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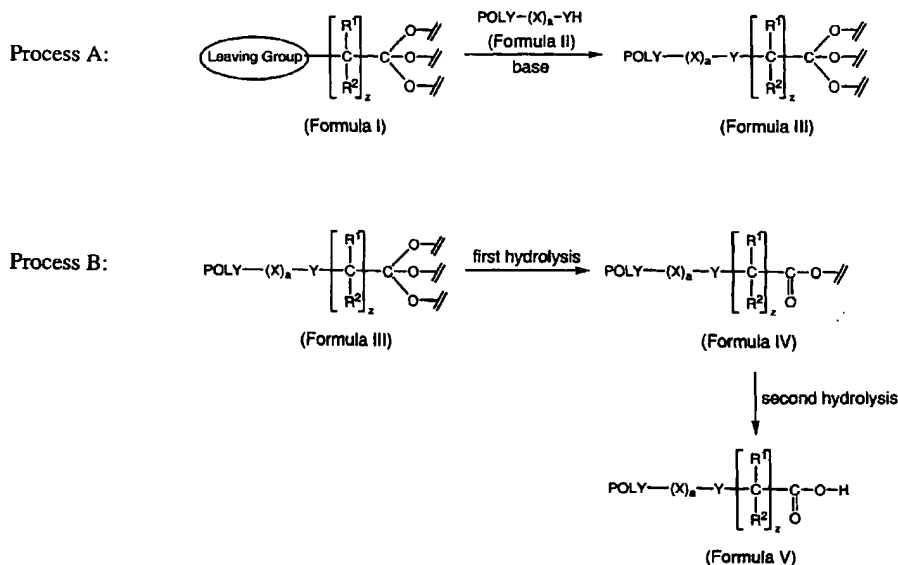
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(54) Title: **METHOD FOR PREPARING WATER-SOLUBLE POLYMER DERIVATIVES BEARING A TERMINAL CARBOXYLIC ACID**



(57) Abstract: A method is provided for preparing water-soluble polymer derivatives bearing a terminal carboxylic acid or ester thereof. The method involves the hydrolyzing an ortho ester of a water-soluble polymer so as provide the corresponding acid. In addition, the invention provides water-soluble polymers bearing a terminal carboxylic acid or ester thereof, intermediates and reagents useful in carrying out the method, as well as gels, pharmaceutical formulations, conjugates related to the described water-soluble polymer derivatives.

## METHOD FOR PREPARING WATER-SOLUBLE POLYMER DERIVATIVES BEARING A TERMINAL CARBOXYLIC ACID

### FIELD OF THE INVENTION

5           The present invention relates generally to novel methods for preparing polymer derivatives that comprise a terminal carboxylic acid or ester thereof. In addition, the invention relates to polymers, conjugates of the polymers, conjugation methods, and intermediates as well as methods for preparing the intermediates. Furthermore, the invention relates to pharmaceutical preparations, synthetic  
10       methods, and the like.

### BACKGROUND OF THE INVENTION

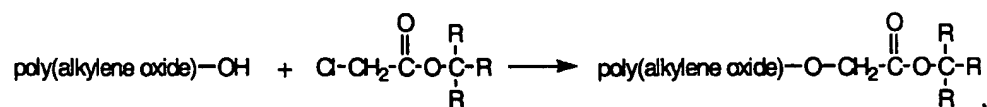
          Conjugating a water-soluble polymer such as poly(ethylene glycol) (or "PEG") to a biologically active agent results in a polymer-active agent conjugate  
15       that often has advantageous properties over the corresponding "unconjugated" version of the active agent. Among other advantages, conjugated forms of active agents have increased half-lives and are less immunogenic. When PEG is used to form a polymer-active agent conjugate, the conjugated active agent is conventionally referred to as "PEGylated." Commercially available PEGylated  
20       preparations include PEGASYS<sup>®</sup> PEGylated interferon alpha-2a (Hoffmann-La Roche, Nutley, NJ), PEG-INTRON<sup>®</sup> PEGylated interferon alpha-2b (Schering Corp., Kenilworth, NJ), NEULASTA<sup>™</sup> PEG-filgrastim (Amgen Inc., Thousand Oaks, CA) and SOMAVERT<sup>®</sup> pegvisomant (Pfizer, New York, NY). The commercial success of these preparations attests to the value of PEGylation  
25       technology.

          Polymers bearing a terminal carboxylic acid are useful, either directly or indirectly, in conjugation reactions with active agents and other substances. For example, carboxylic acids can be reacted directly with an amino or hydroxyl group of an active agent, thereby forming a conjugate. Indirectly, polymers bearing a  
30       terminal carboxylic acid (which acts as a reactive electrophilic group) can serve as a

convenient starting material for preparing other polymer derivatives bearing functional groups other than carboxylic acids. Polymers bearing a functional group other than a carboxylic acid can then form conjugates with active agents bearing a suitable reactive group.

5           Methods for preparing certain water-soluble polymers bearing a terminal carboxylic acid have been described. For example U.S. Patent No. 5,681,567 describes reacting a poly(alkylene oxide) with a tertiary-alkyl haloacetate to thereby form a tertiary-alkyl ester of a poly(alkylene oxide) carboxylic acid. Schematically, the reaction using a tertiary-alkyl chloroacetate can be represented as follows:

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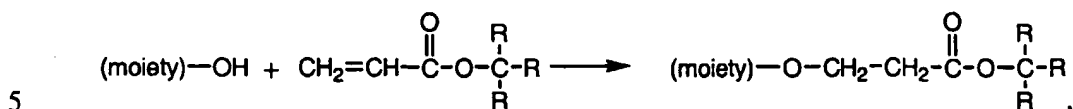


wherein each R is alkyl. Subsequent reaction of the ester with an acid removes the tertiary alkyl moiety, which yields the corresponding acetic acid. This method,  
 15 however, only results in polymers bearing a terminal acetic acid moiety. Polymer derivatives synthesized to terminate in an acetic acid moiety are sometimes referred to as "carboxymethylated" polymers.

Polymer derivatives bearing a terminal acetic acid can be further reacted to form polymer derivatives bearing other reactive moieties. For example, a  
 20 succinimidyl ester of carboxymethyl PEG can be formed. This succinimidyl ester, however, is so reactive that it hydrolyzes almost immediately in aqueous solution. Thus, the practical utility of PEG derivatives bearing a terminal acetic acid moiety can be low given the overly reactive nature of these derivatives.

Another method for preparing certain water-soluble polymers bearing a  
 25 terminal carboxylic acid derivative is described in U.S. Patent No. 5,523,479. In this approach, a moiety having a molecular weight of from 32 to 6000 and having from one to 6 hydroxyl groups is reacted with a tertiary alkyl ester of a beta-unsaturated carboxylic acid to yield a product having a terminal ester.

Schematically, the reaction in can be represented as follows (the moiety is presented as having a single hydroxyl group and the tertiary alkyl ester of a beta-unsaturated carboxylic acid is represented by tertiary alkyl ester of acrylic acid)



wherein R is alkyl. A subsequent hydrolytic step transforms the ester into the corresponding propanoic acid.

While providing polymer derivatives that lack a reactive acetic acid moiety, this method suffers from other drawbacks. First, the method inherently provides for only propanoic acid derivatives. In addition, the best reported conversion of the hydroxyl group to the ester is less than 85%. Finally, only moieties having a molecular weight between 32 and 6000 are described in connection with carrying out the method. There remains a need, however, to provide a method that can prepare acids other than propanoic acid derivatives, result in conversion to an ester and/or acid of greater than 85%, and be used with moieties having a molecular weight outside of the range of 32 to 6000.

U.S. Patent No. 5,672,662, discloses PEG derivatives having a terminal propanoic acid or butanoic acid moiety that can be used to prepare active esters suitable for conjugation to proteins or other molecules bearing amino groups. The active esters described in U.S. Patent No. 5,672,662 exhibit greater stability in solution than active esters of carboxymethylated PEG, and are thus better suited for conjugation to biologically active molecules. The method described for preparing these PEG derivatives having a terminal propanoic or butanoic moiety, however, involves numerous steps and only results in about 80% substitution into the carboxylic acid moiety. As a consequence, the method described in U.S. Patent No. 5,672,662 requires expensive and time-consuming purification steps in order to provide a pharmaceutical grade product.

Thus, there remains a need in the art for improved methods for preparing polymer derivatives bearing a terminal carboxylic acid. In addition, there continues to be a need to provide novel polymers bearing a carboxylic acid moiety that are useful for conjugation reactions and further functionalization. The present  
5 invention addresses these and other needs in the art by providing, *inter alia*, novel methods for the efficient preparation of polymer derivatives bearing a terminal carboxylic acid.

#### SUMMARY OF THE INVENTION

10 Accordingly, it is a primary object of this invention to provide a method for making a carboxylic acid of a water-soluble polymer comprising the steps of (a) reacting a water-soluble polymer segment having at least one alkoxide ion or thiolate ion with an ortho ester comprised of a suitable leaving group to form an ortho ester of a water-soluble polymer; and (b) subjecting the ortho ester of a  
15 water-soluble polymer formed in step (a) to one or more hydrolysis steps so as to provide the corresponding carboxylic acid of a water-soluble polymer.

It is another object of the invention to provide an ortho ester useful in the method for making the carboxylic acid of the water-soluble polymer. Thus, this object of the invention comprises carrying out step (a) recited in the immediately  
20 preceding paragraph.

It is yet another object of the invention to provide a carboxylic acid of a water-soluble polymer prepared by a method described herein.

It is a further object of the invention to provide a carboxylic acid or ester thereof of a water-soluble polymer.

25 It is still another object of the invention to provide an ortho ester of a water-soluble polymer.

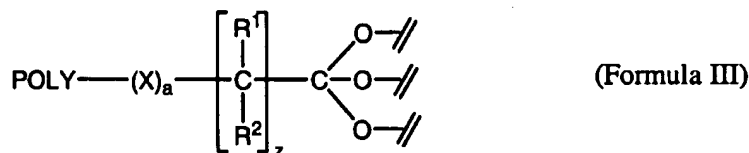
It is still yet another object of the invention to provide gels, conjugates, and pharmaceutical compositions comprising a polymer described herein.

It is another object of the invention to provide methods for preparing each of the gels, conjugates, and pharmaceutical compositions described herein.

It is a further object of the invention to provide methods for administering each of the gels, conjugates, and pharmaceutical compositions described herein,  
 5 comprising the step of delivering the preparation to a patient.

Additional objects, advantages and novel features of the invention will be set forth in the description that follows, and in part, will become apparent to those skilled in the art upon the following, or may be learned by practice of the invention.

In one embodiment of the invention then, an ortho ester of a water-soluble  
 10 polymer is provided. Among other uses, the ortho ester has utility as an intermediate in the synthesis of a water-soluble polymer bearing a terminal carboxylic acid group. The ortho ester of the water-soluble polymer preferably comprises the following structure:



wherein:

POLY is a water-soluble polymer segment;

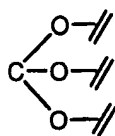
20 (a) is either zero or one;

X, when present, is a spacer moiety;

(z) is an integer from 1 to 24;

R<sup>1</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl,  
 25 alkynyl, substituted alkynyl, aryl, and substituted aryl;

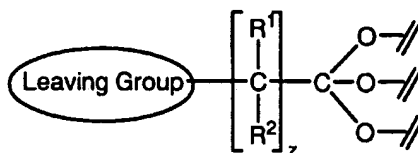
R<sup>2</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and



represents a residue of an ortho ester moiety.

In another embodiment, the present invention provides a method for making an ortho ester of a water-soluble polymer. The method comprises the step of reacting, in the presence of a base, a water-soluble polymer segment having at least one hydroxyl or thiol group with an ortho ester comprised of a suitable leaving group. It is preferred that the water-soluble polymer segment has at least one hydroxyl group and lacks any thiol groups.

Typically, although not necessarily, the ortho ester comprising a suitable leaving group is comprised of the following structure:



(Formula I)

wherein:

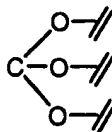


is the suitable leaving group;

(z) is an integer from 1 to 24;

$R^1$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

$R^2$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

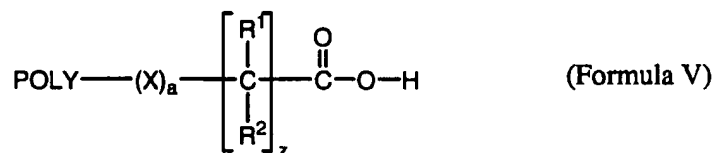


represents a residue of an ortho ester moiety.

In a further embodiment of the invention, a method for making a carboxylic acid of a water-soluble polymer is provided. The method comprises the step of subjecting an ortho ester of a water-soluble polymer to one or more hydrolysis steps so as to provide the corresponding carboxylic acid of a water-soluble polymer.

5 Although a single hydrolysis step can be performed, it is preferred that two sequential hydrolysis steps are performed. Exemplary double hydrolysis steps include an initial base hydrolysis step followed by a second base hydrolysis step and an initial acid hydrolysis step followed by a base hydrolysis step.

10 In another embodiment, the invention provides a carboxylic acid of a water-soluble polymer prepared by the method. In this regard, polymers such as those having the following structure can be prepared:



15

wherein:

POLY is a water-soluble polymer segment;

(a) is either zero or one;

X, when present, is a spacer moiety;

20 (z) is an integer from 1 to 24;

$\text{R}^1$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

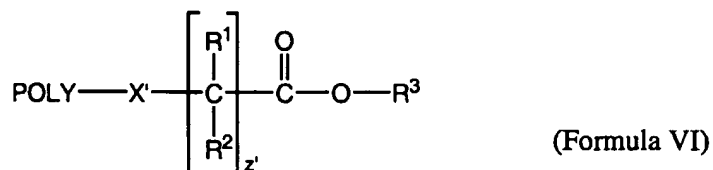
25  $\text{R}^2$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.

The corresponding ester versions of these acids are also included wherein the terminal carboxylic moiety " $-\text{C}(\text{O})\text{OH}$ " of the polymer is replaced by "-



C(O)OR<sup>3</sup>" wherein R<sup>3</sup> is defined as an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.

Exemplary polymers bearing a terminal carboxylic acid or ester thereof  
 5 include those having the following structure:



10

wherein:

POLY is a water-soluble polymer segment;

X' is a spacer moiety with the proviso that when the spacer moiety is only one atom, the one atom is not O or S;

15 (z') is an integer from 3 to 24;

R<sup>1</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

20 R<sup>2</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

R<sup>3</sup> is H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, and substituted alkynyl.

Thus, it is preferred that R<sup>3</sup> is nonaromatic.

25 For any structure comprising a water-soluble polymer segment, any polymer that is water-soluble can be used and the invention is not limited in this regard. Preferred water-soluble polymer segments, however, are terminally end-capped on

one terminus. In addition, water-soluble polymer segments having a mass average molecular mass of less than about 100,000 Daltons are preferred.

#### BRIEF DESCRIPTION OF THE DRAWING

5           Figure 1 is a schematic representation of one approach for preparing a water-soluble polymer bearing a terminal carboxylic acid according to the invention.

#### DETAILED DESCRIPTION OF THE INVENTION

##### 10       OVERVIEW AND DEFINITIONS

Before describing the present invention in detail, it is to be understood that this invention is not limited to the particular polymers, synthetic techniques, active agents, and the like as such may vary. It is also to be understood that the terminology used herein is for describing particular embodiments only, and is not  
15       intended to be limiting.

It must be noted that, as used in this specification and the claims, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to a "polymer" includes a single polymer as well as two or more of the same or different polymers, reference to a  
20       "conjugate" refers to a single conjugate as well as two or more of the same or different conjugates, reference to an "excipient" includes a single excipient as well as two or more of the same or different excipients, and the like.

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions described below.

25       "PEG," "polyethylene glycol" and "poly(ethylene glycol)" as used herein, are meant to encompass any water-soluble poly(ethylene oxide). Typically, PEGs for use in accordance with the invention comprise the following structure  
"-O(CH<sub>2</sub>CH<sub>2</sub>O)<sub>m</sub>-" where (m) is 2 to 4000. As used herein, PEG also includes  
-- depending upon whether or not the terminal oxygen(s) has been displaced -- the

following similar structures  $-\text{CH}_2\text{CH}_2-\text{O}(\text{CH}_2\text{CH}_2\text{O})_m-\text{CH}_2\text{CH}_2-$  and  $-(\text{CH}_2\text{CH}_2\text{O})_m-$  where (m) is 2 to 4000. When the PEG further comprises a linker moiety (to be described in greater detail below), the atoms comprising the linker, when covalently attached to a water-soluble polymer segment, do not result in the formation of an oxygen-oxygen bond (i.e., an  $-\text{O}-\text{O}-$  or peroxide linkage). Throughout the specification and claims, it should be remembered that the term "PEG" includes structures having various terminal or "end capping" groups and so forth. The term "PEG" also means a polymer that contains a majority, that is to say, greater than 50%, of  $-\text{CH}_2\text{CH}_2\text{O}-$  monomeric subunits. With respect to specific forms, the PEG can take any number of a variety of molecular weights, as well as structures or geometries such as "branched," "linear," "forked," "multifunctional," and the like, to be described in greater detail below.

The terms "end-capped" or "terminally capped" are used interchangeably herein to refer to a terminal or endpoint of a polymer that terminates with an end-capping moiety. Typically, although not necessarily, the end-capping moiety comprises a hydroxy or  $\text{C}_{1-20}$  alkoxy group. Thus, examples of end-capping moieties include alkoxy (e.g., methoxy, ethoxy and benzyloxy), as well as aryl, heteroaryl, cyclo, heterocyclo, and the like. In addition, saturated, unsaturated, substituted and unsubstituted forms of each of the foregoing are envisioned. Moreover, the end-capping group can also be a silane. The end-capping group can also advantageously comprise a detectable label. When the polymer has an end-capping group comprising a detectable label, the amount or location of the polymer and/or the moiety (e.g., active agent) to which the polymer is coupled to of interest can be determined by using a suitable detector. Such labels include, without limitation, fluorescers, chemiluminescers, moieties used in enzyme labeling, colorimetric (e.g., dyes), metal ions, radioactive moieties, and the like. Suitable detectors include photometers, films, spectrometers, and the like.

"Non-naturally occurring" with respect to a polymer or water-soluble polymer segment means a polymer that in its entirety is not found in nature. A non-naturally occurring polymer or water-soluble polymer segment may, however,

contain one or more subunits or portions of a subunit that are naturally occurring, so long as the overall polymer structure is not found in nature.

The term "water soluble" as in a "water-soluble polymer segment" and "water-soluble polymer" is any segment or polymer that is soluble in water at room temperature. Typically, a water-soluble polymer or segment will transmit at least about 75%, more preferably at least about 95% of light, transmitted by the same solution after filtering. On a weight basis, a water-soluble polymer or segment thereof will preferably be at least about 35% (by weight) soluble in water, more preferably at least about 50% (by weight) soluble in water, still more preferably about 70% (by weight) soluble in water, and still more preferably about 85% (by weight) soluble in water. It is most preferred, however, that the water-soluble polymer or segment is about 95% (by weight) soluble in water or completely soluble in water.

"Molecular mass" in the context of a water-soluble, non-naturally occurring polymer of the invention such as PEG, refers to the nominal average molecular mass of a polymer, typically determined by size exclusion chromatography, light scattering techniques, or intrinsic velocity determination in 1,2,4-trichlorobenzene. The polymers of the invention are typically polydisperse, possessing low polydispersity values of preferably less than about 1.2, more preferably less than about 1.15, still more preferably less than about 1.10, yet still more preferably less than about 1.05, and most preferably less than about 1.03.

"Thiol derivative," in the context of a water-soluble polymer, means a polymer having at least one terminus that is a thiol group (-SH), a thiolate (-S<sup>-</sup>) or a protected thiol, that is to say, a thiol group in its protected form. Typical thiol protecting groups include thioether, thioester, or disulfide. Exemplary protecting groups for thiols can be found in Greene *et al.*, "PROTECTIVE GROUPS IN ORGANIC SYNTHESIS," 3<sup>rd</sup> Edition, John Wiley and Sons, Inc., New York, 1999.

As used herein, the term "carboxylic acid" as in a "carboxylic acid" derivative is a moiety having a  $\text{-}\overset{\text{O}}{\parallel}\text{C-OH}$  functional group [also represented as a "-COOH" or -C(O)OH]. Unless the context clearly dictates otherwise, the term

carboxylic acid includes not only the acid form, but corresponding esters and protected forms as well. Reference is again made to Greene *et al. supra* with respect suitable protecting groups for carboxylic acids.

5       The term "reactive" or "activated" when used in conjunction with a particular functional group, refers to a reactive functional group that reacts readily with an electrophile or a nucleophile on another molecule. This is in contrast to those groups that require strong catalysts or highly impractical reaction conditions in order to react (i.e., a "nonreactive" or "inert" group).

10       The terms "protected" or "protecting group" or "protective group" refer to the presence of a moiety (i.e., the protecting group) that prevents or blocks reaction of a particular chemically reactive functional group in a molecule under certain reaction conditions. The protecting group will vary depending upon the type of chemically reactive group being protected as well as the reaction conditions to be employed and the presence of additional reactive or protecting groups in the  
15       molecule, if any. Protecting groups known in the art can be found in Greene *et al., supra*.

As used herein, the term "functional group" or any synonym thereof is meant to encompass protected forms thereof.

20       The term "spacer" or "spacer moiety" is used herein to refer to an atom or a collection of atoms optionally used to link interconnecting moieties such as a terminus of a water-soluble polymer segment and an electrophile. The spacer moieties of the invention may be hydrolytically stable or may include a physiologically hydrolyzable or enzymatically degradable linkage.

25       "Alkyl" refers to a hydrocarbon chain, typically ranging from about 1 to 20 atoms in length. Such hydrocarbon chains are preferably but not necessarily saturated and may be branched or straight chain, although typically straight chain is preferred. Exemplary alkyl groups include ethyl, propyl, butyl, pentyl, 1-methylbutyl, 1-ethylpropyl, 3-methylpentyl, and the like. As used herein, "alkyl" includes cycloalkyl when three or more carbon atoms are referenced.

"Lower alkyl" refers to an alkyl group containing from 1 to 6 carbon atoms, and may be straight chain or branched, as exemplified by methyl, ethyl, *n*-butyl, *iso*-butyl, and *tert*-butyl.

5 "Cycloalkyl" refers to a saturated or unsaturated cyclic hydrocarbon chain, including bridged, fused, or spiro cyclic compounds, preferably made up of 3 to about 12 carbon atoms, more preferably 3 to about 8.

"Non-interfering substituents" are those groups that, when present in a molecule, are typically non-reactive with other functional groups contained within the molecule.

10 The term "substituted" as in, for example, "substituted alkyl," refers to a moiety (e.g., an alkyl group) substituted with one or more non-interfering substituents, such as, but not limited to: C<sub>3</sub>-C<sub>8</sub> cycloalkyl, e.g., cyclopropyl, cyclobutyl, and the like; halo, e.g., fluoro, chloro, bromo, and iodo; cyano; alkoxy, lower phenyl (e.g., 0-2 substituted phenyl); substituted phenyl; and the like.

15 "Substituted aryl" is aryl having one or more non-interfering groups as a substituent. For substitutions on a phenyl ring, the substituents may be in any orientation (i.e., ortho, meta, or para).

"Alkoxy" refers to an -O-R group, wherein R is alkyl or substituted alkyl, preferably C<sub>1</sub>-C<sub>20</sub> alkyl (e.g., methoxy, ethoxy, propyloxy, benzyl, etc.), preferably  
20 C<sub>1</sub>-C<sub>7</sub>.

As used herein, "alkenyl" refers to a branched or unbranched hydrocarbon group of 1 to 15 atoms in length, containing at least one double bond, such as ethenyl, *n*-propenyl, isopropenyl, *n*-butenyl, isobutenyl, octenyl, decenyl, tetradecenyl, and the like.

25 The term "alkynyl" as used herein refers to a branched or unbranched hydrocarbon group of 2 to 15 atoms in length, containing at least one triple bond, ethynyl, *n*-propynyl, isopropynyl, *n*-butynyl, isobutynyl, octynyl, decynyl, and so forth.

"Aryl" means one or more aromatic rings, each of 5 or 6 core carbon atoms.  
30 Aryl includes multiple aryl rings that may be fused, as in naphthyl or unfused, as in

biphenyl. Aryl rings may also be fused or unfused with one or more cyclic hydrocarbon, heteroaryl, or heterocyclic rings. As used herein, "aryl" includes heteroaryl.

"Heteroaryl" is an aryl group containing from one to four heteroatoms, preferably N, O, or S, or a combination thereof. Heteroaryl rings may also be fused with one or more cyclic hydrocarbon, heterocyclic, aryl, or heteroaryl rings.

"Heterocycle" or "heterocyclic" means one or more rings of 5-12 atoms, preferably 5-7 atoms, with or without unsaturation or aromatic character and having at least one ring atom which is not a carbon. Preferred heteroatoms include sulfur, oxygen, and nitrogen.

"Substituted heteroaryl" is heteroaryl having one or more non-interfering groups as substituents.

"Substituted heterocycle" is a heterocycle having one or more side chains formed from non-interfering substituents.

"Electrophile" refers to an ion or atom or collection of atoms, that may be ionic, having an electrophilic center, i.e., a center that is electron seeking, capable of reacting with a nucleophile.

"Nucleophile" refers to an ion or atom or collection of atoms that may be ionic having a nucleophilic center, i.e., a center that is seeking an electrophilic center or with an electrophile.

A "physiologically cleavable" or "hydrolyzable" or "degradable" bond is a relatively weak bond that reacts with water (i.e., is hydrolyzed) under physiological conditions. The tendency of a bond to hydrolyze in water will depend not only on the general type of linkage connecting two central atoms but also on the substituents attached to these central atoms. Appropriate hydrolytically unstable or weak linkages include, but are not limited to, carboxylate ester, phosphate ester, anhydrides, acetals, ketals, acyloxyalkyl ether, imines, ortho esters, peptides and oligonucleotides.

An "enzymatically degradable linkage" means a linkage that is subject to degradation by one or more enzymes.

5 A "hydrolytically stable" linkage or bond refers to a chemical bond, typically a covalent bond, that is substantially stable in water, that is to say, does not undergo hydrolysis under physiological conditions to any appreciable extent over an extended period of time. Examples of hydrolytically stable linkages include but are not limited to the following: carbon-carbon bonds (e.g., in aliphatic chains), ethers, amides, urethanes, and the like. Generally, a hydrolytically stable linkage is one that exhibits a rate of hydrolysis of less than about 1-2% per day  
10 under physiological conditions. Hydrolysis rates of representative chemical bonds can be found in most standard chemistry textbooks.

The terms "active agent" and "biologically active agent" are used interchangeably herein and are defined to include any agent, drug, compound, composition of matter or mixture that provides some pharmacologic, often  
15 beneficial, effect that can be demonstrated *in-vivo* or *in vitro*. This includes foods, food supplements, nutrients, nutraceuticals, drugs, vaccines, antibodies, vitamins, and other beneficial agents. As used herein, these terms further include any physiologically or pharmacologically active substance that produces a localized or systemic effect in a patient.

20 "Pharmaceutically acceptable excipient" or "pharmaceutically acceptable carrier" refers to an excipient that can be included in the compositions of the invention and that causes no significant adverse toxicological effects to the patient.

"Pharmacologically effective amount," "physiologically effective amount," and "therapeutically effective amount" are used interchangeably herein to mean the  
25 amount of a polymer-active agent conjugate present in a pharmaceutical preparation that is needed to provide a desired level of active agent and/or conjugate in the bloodstream or in the target tissue. The precise amount will depend upon numerous factors, e.g., the particular active agent, the components and physical characteristics of the pharmaceutical preparation, intended patient population, patient considerations,  
30 and the like, and can readily be determined by one of ordinary skill in the art, based upon the information provided herein and available in the relevant literature.



"Multifunctional" in the context of a polymer of the invention means a polymer having 3 or more functional groups contained therein, where the functional groups may be the same or different. Multifunctional polymers of the invention will typically contain from about 3-100 functional groups, or from 3-50 functional groups, or from 3-25 functional groups, or from 3-15 functional groups, or from 3 to 10 functional groups, or will contain 3, 4, 5, 6, 7, 8, 9 or 10 functional groups within the polymer. A "difunctional" polymer means a polymer having two functional groups contained therein, either the same (i.e., homodifunctional) or different (i.e., heterodifunctional).

"Branched," in reference to the geometry or overall structure of a polymer, refers to polymer having 2 or more polymer "arms." A branched polymer may possess 2 polymer arms, 3 polymer arms, 4 polymer arms, 6 polymer arms, 8 polymer arms or more. One particular type of highly branched polymer is a dendritic polymer or dendrimer, which, for the purposes of the invention, is considered to possess a structure distinct from that of a branched polymer.

A "dendrimer" or dendritic polymer is a globular, size monodisperse polymer in which all bonds emerge radially from a central focal point or core with a regular branching pattern and with repeat units that each contribute a branch point. Dendrimers exhibit certain dendritic state properties such as core encapsulation, making them unique from other types of polymers.

A basic or acidic reactant described herein includes neutral, charged, and any corresponding salt forms thereof.

The term "patient," refers to a living organism suffering from or prone to a condition that can be prevented or treated by administration of a conjugate as provided herein, and includes both humans and animals.

"Optional" and "optionally" mean that the subsequently described circumstance may or may not occur, so that the description includes instances where the circumstance occurs and instances where it does not.

As used herein, the "halo" designator (e.g., fluoro, chloro, iodo, bromo, and so forth) is generally used when the halogen is attached to a molecule, while the suffix "ide" (e.g., fluoride, chloride, iodide, bromide, and so forth) is used when the

ionic form is used when the halogen exists in its independent ionic form (e.g., such as when a leaving group leaves a molecule).

In the context of the present discussion, it should be recognized that the definition of a variable provided with respect to one structure or formula is  
5 applicable to the same variable repeated in a different structure, unless the context dictates otherwise. Thus, for example, the definition of "POLY," "a spacer moiety," "(z)," and so forth with respect to an ortho ester of a water-soluble polymer is equally applicable to a water-soluble polymer bearing a carboxylic acid.

## 10 THE METHOD

The present methods for preparing a carboxylic acid of a water-soluble polymer have several advantages. As shown herein, for example, water-soluble polymers bearing a terminal carboxylic acid moiety can be provided in high purity. Although prior art approaches result in relatively low purity, conversions of at least  
15 about 85%, more preferably at least about 90%, still more preferably at least about 95%, and most preferably at least about 98% conversion of a precursor molecule into the corresponding carboxylic acid derivative are shown herein. Because water-soluble polymers bearing a terminal carboxylic acid moiety can now be provided in relatively high purity, expensive and time consuming purification steps  
20 are reduced or eliminated entirely.

Another advantage of the current methods for preparing a carboxylic acid of water-soluble polymer is the ability to prepare a larger range of structurally diverse derivatives. Previously described methods necessarily resulted in, for example, certain acetic acid or carboxymethylated derivatives (see U.S. Patent No.  
25 5,681,567), certain propanoic acid derivatives (see U.S. Patent Nos. 5,523,479 and 5,672,662), and certain butanoic acid derivatives (see U.S. Patent No. 5,672,662). These previously described derivatives are necessarily limited to certain structures since the methods used to create them rely on a relatively narrow palette of possible reagents suitable for use with these methods. Advantageously, the present methods

can be used with a relatively large number of reagents, thereby greatly expanding the range of possible structures.

A first method is thus provided to form an ortho ester of a water-soluble polymer, which serves as a useful intermediate in further carrying out a step for subsequent formation of a water-soluble polymer bearing a terminal carboxylic acid. Process A as shown in FIG. 1, depicts one approach for carrying out this first method. One approach for the subsequent formation of a water-soluble polymer bearing a terminal carboxylic acid (Formula V) is shown as process B in FIG. 1. Provided only for assistance in better understanding a synthetic method presented herein, FIG. 1 in no way should be construed as limiting the invention. The various formulae shown in FIG. 1 are described in more detail below.

Initially, the method for forming an ortho ester of a water-soluble polymer comprises the step of reacting a water-soluble polymer segment having at least one alkoxide ion or thiolate ion with an ortho ester comprised of a suitable leaving group (i.e., an ortho ester-containing molecule comprised of a suitable leaving group). Conveniently, and with reference to FIG. 1, the water-soluble polymer segment having at least one alkoxide ion or thiolate ion is prepared by combining a water-soluble polymer having at least one hydroxyl or thiol group (Formula II) in the presence of a suitable base. An ortho ester comprising a suitable leaving group (Formula I) is allowed to react with a water-soluble polymer having at least one hydroxyl or thiol group (Formula II) to form an ortho ester comprised of a suitable leaving group (Formula III).

The base used in this approach, however, must be one that will form an alkoxide (i.e.,  $R-O^-$ ) or thiolate (i.e.,  $R-S^-$ ) of the water-soluble polymer having at least one hydroxyl or thiol group, respectively. Thus, for example, the base transforms  $POLY-(X)_a-OH$  into  $POLY-(X)_a-O^-$  and  $POLY-(X)_a-SH$  into  $POLY-(X)_a-S^-$ . It is further believed that the water-soluble polymer, now bearing an alkoxide or thiolate moiety, in turn reacts via a  $S_N2$  reaction mechanism with the ortho ester having a suitable leaving group (Formula I). As will be recognized by those of ordinary skill in the art, this approach corresponds to Williamson ether

synthesis, and the principles and techniques generally used in a Williamson ether synthesis are applicable here as well.

Nonlimiting examples of bases suitable to form an alkoxide of an alcohol or a thiolate of a thiol-containing compound include sodium, sodium hydroxide, potassium, potassium hydroxide, sodium hydride, potassium hydride, sodium methoxide, potassium methoxide, sodium tert-butoxide, potassium tert-butoxide, sodium carbonate, and potassium carbonate. Preferred bases for use in accordance with this step, however, include those selected from the group consisting of sodium, potassium, sodium hydride, potassium hydride, sodium methoxide, potassium methoxide, sodium tert-butoxide, and potassium tert-butoxide.

In addition, the water-soluble polymer segment having at least one alkoxide ion or thiolate ion can conveniently be provided via a polymerization reaction, as will be discussed in more detail below. In this approach for providing the water-soluble polymer segment, it is preferred that the water-soluble polymer segment has at least one alkoxide ion.

Generally, although not necessarily, an excess of the ortho ester comprising a suitable leaving group (Formula I) is allowed to react with the water-soluble polymer bearing at least one alkoxide ion or thiolate ion (Formula II). Typically, the amount of the ortho ester comprising a suitable leaving group (Formula I) represents at least a molar equivalent to the number available hydroxyl or thiol groups in the water-soluble polymer having at least one hydroxyl or thiol group (Formula II). Heterofunctional polymer species (i.e., species bearing two or more different terminal functional groups) can be prepared by using nonstoichiometric amounts of the ortho ester comprising a suitable leaving group (Formula I). That is, heterofunctional species are formed when the total number of moles of available hydroxyl or thiol groups on the water-soluble polymer having at least one hydroxyl or thiol group (Formula II) exceeds the total number of moles of the ortho ester comprising a suitable leaving group (Formula I) added to the reaction.

The ortho ester of the water-soluble polymer (Formula III) can be prepared by other means and the invention is not limited simply to process A as depicted in FIG. 1. For example, an ortho ester comprising at least one initiator site suitable for

polymerization can be used to grow one or more water-soluble polymer segments. Using this approach, an ortho ester comprising at least one initiator site (e.g., an alkoxide moiety) and a reactive monomer (e.g., ethylene oxide) are combined and the reaction is allowed to proceed until all of the reactive monomer is exhausted or  
5 the reaction is terminated by, for example, neutralizing the reaction medium. The last reactive monomer, e.g., ethylene oxide, added to the growing chain may conveniently provide an alkoxide ion or thiolate ion for subsequent reaction with, for example, an ortho ester comprised of a suitable leaving group.

Specifically, the following steps can be followed in order to build the  
10 water-soluble polymer segment directly onto an ortho ester comprising at least one initiator site: (i) providing an ortho ester comprising at least one active anionic site suitable for initiating polymerization; (ii) contacting the anionic site of the ortho ester with a reactive monomer capable of polymerizing, to thereby initiate  
15 polymerization of the reactive monomer onto the ortho ester precursor; (iii) adding addition reactive monomers to the ortho acid precursor to form one or more polymer chain(s); (iv) allowing said contacting to continue until a desired length of the polymer chain(s) is reached; and (v) terminating the reaction to achieve an ortho ester of a water-soluble polymer.

Any reactive monomer can be used to "grow" the polymer chain(s) so long  
20 as the resulting polymer chain is water soluble. It is particularly preferred, however, that the reactive monomer is ethylene oxide, thereby providing poly(ethylene oxide) chain(s). Growth of the polymer chain(s), including the initial attachment of the reactive monomer to the initiator site, can be effected through, for example, an alkoxide ion (i.e.,  $R-O^-$ ). These and other techniques are known to  
25 those of ordinary skill in the art and are referenced in, for example, Odian, Chap. 7, Principles of Polymerization, 3<sup>rd</sup> Ed., McGraw-Hill, 1991.

Growth of the polymer chain(s) continues until the desired molecular weight is achieved. Thus, for example, neutralizing the reaction medium halts the growth of the polymer chain(s). In addition, adding a specific weight or amount of the  
30 reactive monomer and allowing the polymerization to proceed until all reactive monomer is exhausted results in a polymer chain having a corresponding molecular

weight. Once the polymer chain(s) are formed, an end-capping group can be added using conventional techniques. For example, an alkyl halide (e.g., methyl halide or methyl *p*-toluenesulfonate) can be reacted with the exposed terminal (the terminal distal to the ortho ester functionality) of the polymer chain.

5           A related, although different, polymerization approach can also be used to provide an ortho ester of a water-soluble polymer. In this related approach, the polymerization is carried out to first form a polymer chain that can be subsequently transformed into the ortho ester derivative. Thus, for example, an alkoxy alcoholate salt such as sodium 2-methoxy ethanolate ( $\text{Na}^+ \cdot \text{OCH}_2\text{CH}_2\text{OCH}_3$ ) can initiate  
10 polymerization of ethylene oxide by essentially following the same procedure outlined above. Assuming that the final monomer added to the polymer chain leaves a reactive group such as an alkoxide (as in the case of ethylene oxide), the polymer chain can then be reacted with an ortho ester comprising a suitable leaving group. To the extent that the polymer chain does not leave a group (e.g., an  
15 alkoxide) suitable for direct attachment to an ortho ester-containing reagent, additional modifications to the polymer chain can be made such that an ortho ester can be attached.

Use of an alkoxy alcoholate salt as an initiator of the polymer results in an ortho ester of a water-soluble polymer comprising a single ortho ester functionality.  
20 Polymers comprising two ortho esters functionalities (a bifunctional polymer) can result when dialcoholate salts (e.g.  $2\text{Na}^+ \cdot \text{OCH}_2\text{CH}_2\text{O}^-$ ) are used in place of alkoxy alcoholate salts. As described above, an optional capping step can also be performed with this polymerization approach.

Returning to FIG. 1, the ortho ester of a water-soluble polymer (Formula III)  
25 can be converted into a water-soluble polymer bearing a terminal carboxylic (Formula V). The conversion into the corresponding carboxylic acid derivative is advantageously accomplished efficiently and in high yield by performing one or more hydrolysis steps. Either acid-catalyzed hydrolysis or acid-catalyzed hydrolysis followed by base-promoted hydrolysis can provide the water-soluble  
30 polymer bearing a terminal carboxylic acid (Formula V).

Although conversion into the carboxylic acid can be carried out in a single hydrolysis step via acid-catalyzed hydrolysis, it is believed that this single hydrolytic approach is inefficient in terms of time. It has been found that two hydrolysis steps, however, increases the speed for converting the carboxylic acid  
5 from the corresponding ortho ester.

In a two hydrolysis step approach, a first hydrolysis step results in the ortho ester functionality being transformed into an ester (Formula IV). A second hydrolysis step, in turn, converts the ester (Formula IV) to the corresponding polymer bearing a terminal carboxylic acid (Formula IV).

10 The first hydrolysis step should be acid-catalyzed hydrolysis. The ortho ester functionality can be cleaved by mild aqueous acidic conditions such as *p*-toluenesulfonic acid (*p*-TsOH) and pyridine in water, and NaHSO<sub>4</sub> and 1,2-dimethoxyethane (DME) in water at 0 °C for 20 minutes. See Just *et al.* (1983) *Can. J. Chem.* 61:712 and Corey *et al.* (1986) *Tetrahedron Lett.* 27:2199,  
15 respectively. Examples of other acids suitable for use in acid-catalyzed hydrolysis include, without limitation, hydrofluoric acid (HF), hydrochloric acid (HCl), hydrobromic acid (HBr), hydroiodic acid (HI), nitric acid (HNO<sub>3</sub>), perchloric acid (HClO<sub>4</sub>), sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), acetic acid (CH<sub>3</sub>CO<sub>2</sub>H), carbonic acid H<sub>2</sub>CO<sub>3</sub>, phosphoric acid (H<sub>3</sub>PO<sub>4</sub>), oxalic acid (H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>), and formic acid (HCOOH).

20 The second hydrolysis step is typically a base-promoted hydrolysis step. The ester (Formula IV) of the first hydrolysis step is treated with a base. For base-promoted hydrolysis, the ortho ester functionality is treated with any aqueous base, such as lithium hydroxide (LiOH), sodium hydroxide (NaOH), potassium hydroxide (KOH), rubidium hydroxide (RuOH), cesium hydroxide [Cs(OH)<sub>2</sub>],  
25 strontium hydroxide [Sr(OH)<sub>2</sub>], barium hydroxide [Ba(OH)<sub>2</sub>], ammonium hydroxide (NH<sub>4</sub>OH), magnesium hydroxide [Mg(OH)<sub>2</sub>], calcium hydroxide [Ca(OH)<sub>2</sub>], sodium acetate (NaCH<sub>3</sub>CO<sub>2</sub>), potassium acetate (KCH<sub>3</sub>CO<sub>2</sub>), sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>), potassium carbonate (K<sub>2</sub>CO<sub>3</sub>), lithium carbonate (Li<sub>2</sub>CO<sub>3</sub>), sodium phosphate (Na<sub>3</sub>PO<sub>4</sub>), potassium phosphate (K<sub>3</sub>PO<sub>4</sub>), sodium borate  
30 (Na<sub>3</sub>BO<sub>4</sub>), potassium borate (Li<sub>3</sub>PO<sub>4</sub>), and so forth.

The first, and optional second hydrolysis steps can be carried out under increased heat in order to increase the rate reaction.

The steps of the method take place in an appropriate solvent. One of ordinary skill in the art can determine whether any specific solvent is appropriate for any given reaction. Typically and in particular with respect processes A and B as shown in FIG. 1, however, the solvent is preferably a nonpolar solvent or a polar aprotic solvent. Nonlimiting examples of nonpolar solvents include benzene, xylene, dioxane, tetrahydrofuran (THF), *t*-butyl alcohol and toluene. Particularly preferred nonpolar solvents include toluene, xylene, dioxane, tetrahydrofuran, and *t*-butyl alcohol. Exemplary polar aprotic solvents include, but are not limited to, DMSO (dimethyl sulfoxide), HMPA (hexamethylphosphoramide), DMF (dimethylformamide), DMA (dimethylacetamide), NMP (*N*-methylpyrrolidinone).

With respect to hydrolysis, in particular, water is a preferred solvent, although aqueous mixtures of water with other solvents such as water and tetrahydrofuran, water and 1,2-dimethylethane, water and diglyme, as well as other aqueous-containing solvents can be used.

Optionally, the method further comprises the step of recovering the carboxylic acid of the water-soluble polymer. Art-known techniques can be used to recover the polymer and include, for example, precipitating the polymer from solution. The precipitate can then be collected and optionally filtered and/or dried. These and other techniques can be used to isolate and recover the carboxylic acid of the water-soluble polymer.

In addition, the method optionally includes the step of further purifying the carboxylic acid of the water-soluble polymer. Such a purifying step, however, is generally not required given the relatively high degree of converting a precursor (e.g., ortho ester of a water-soluble polymer) into the corresponding carboxylic acid. In any event, art-known techniques such chromatography can be used to purify the polymer.

The acids so produced according to the present method are substantially pure and can be prepared in a one-pot approach. By pure, it is meant that preferably

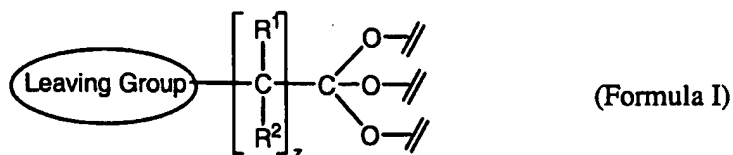


greater than at least about 85%, more preferably greater than at least about 90%, still more preferably greater than at least about 95%, and most preferably greater than at least about 98% of the total amount (either by weight or molar basis) of the water-soluble polymer bearing a hydroxyl or thiol group is converted to  
 5 water-soluble polymer bearing a terminal carboxylic acid.

#### THE ORTHO ESTER OF A WATER-SOLUBLE POLYMER

As indicated above, the method requires use of an ortho ester comprising a suitable leaving group. Structurally, the ortho ester comprises a "branching carbon atom."  
 10 This branching carbon atom is a carbon atom covalently attached to three oxygen atoms, which, in turn, are typically each covalently attached to, for example, an alkyl moiety. Given the tetravalent nature of carbon, the branching carbon atom also comprises a fourth covalent attachment. In the case of the present ortho esters of the invention used to make alkanolic acids, the fourth covalent  
 15 attachment of the branching carbon atom is to a substituted or unsubstituted carbon chain, such as an alkylene chain. Finally, a suitable leaving group is attached, either directly or through a spacer moiety, at the end of the carbon chain that is not attached to the branching carbon atom.

An exemplary structure of an ortho ester comprising a suitable leaving group  
 20 group is provided below.



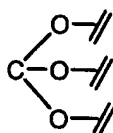
25 wherein:

Leaving Group is the suitable leaving group;

(z) is an integer from 1 to 24;

$R^1$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

5  $R^2$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

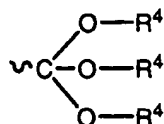


represents a residue of an ortho ester moiety.

With respect Formula I, the suitable leaving group is any atom or group of atoms that can leave the carbon atom to which it is attached. Specifically, a suitable  
10 leaving group is one that can be displaced by an approaching nucleophile. Those of ordinary skill in the art can determine what atom or group of atoms can serve as a suitable leaving group. In addition, routine experimentation can identify whether any specific atom or group of atoms can serve as a suitable leaving group. For example, a proposed leaving group on a molecule comprising an ortho ester can be  
15 tested by reacting the ortho ester with a water-soluble polymer segment having a hydroxyl group; the proposed leaving group is a suitable leaving group if detectable amounts of the corresponding ortho ester of the water-soluble polymer are formed.

Preferred suitable leaving groups include those that are primary (e.g., a primary halo), although leaving groups that are secondary may also be used.  
20 Examples of suitable leaving groups include halogens and sulfonate esters. Among the halogens, bromo, chloro, iodo, and fluoro are preferred, with bromo and chloro being particularly preferred halogen-type leaving groups. With respect to sulfonate esters, methanesulfonate, trifluoromethanesulfonate, trichloromethanesulfonate, 2,2,2-trifluoroethanesulfonate, 2,2,2-trichloroethanesulfonate, and para-  
25 toluenesulfonate are particularly preferred, although other sulfonate esters and similarly constituted leaving groups known to those of ordinary skill in the art can be used as well.

With respect to the specific ortho ester functionality associated with Formula I, any ortho ester functionality can be used and the invention is not limited in this regard. An exemplary ortho ester functionality, however, is comprised of the following structure:



5

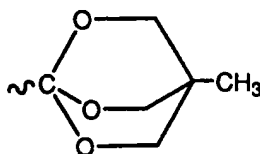
wherein each  $R^4$  is an organic radical independently selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, substituted aryl, and one or more atoms that combine with another  $R^4$  or the remaining  $R^4$  moieties to form a ringed structure.

10

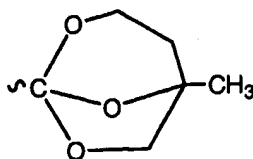
The ortho ester functionality can be acyclic, i.e., lacking a ringed structure. When acyclic, it is preferred that each  $R^4$  in the above-defined structure is independently a  $C_{1-6}$  alkyl (e.g., methyl, ethyl or propyl) or substituted  $C_{1-6}$  alkyl. In addition, the ortho ester functionality can be in form of a "cyclic" or "ringed" structure. In the present context, the term "cyclic" will be understood to include monocyclic, bicyclic, and polycyclic structures. In cyclic versions, the ortho ester functionality is preferably in the form of a substituted or unsubstituted heterocyclic ring comprising from about 6 to about 14 atoms. Preferred substituents for the heterocyclic ring include  $C_{1-6}$  alkyl, such as methyl or ethyl, or substituted  $C_{1-6}$  alkyl. Examples of such preferred cyclic structures include the following bridged heterocyclic rings:

15

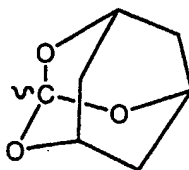
20



4-methyl-2,6,7-trioxabicyclo[2.2.2]octanyl, ("OBO ester");



4-methyl-2,7,8-trioxabicyclo[3.2.1]octanyl, ("ABO ester"); and

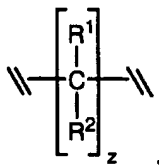


5

2,8,9-trioxatricyclo[3.3.1.1<sup>3,7</sup>]decanyl.

One of ordinary skill in the art can readily envision other cyclic structures that comprise other ortho ester structures (both cyclic and acyclic).

As can be seen with respect to Formula I, the ortho ester comprising a  
 10 suitable leaving group comprises a carbon chain of (z) carbons defined by the following structure:



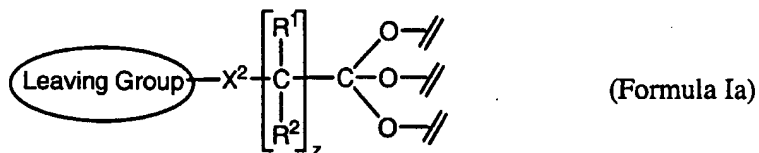
15 wherein (z), each R<sup>1</sup> and each R<sup>2</sup> are as previously defined. Preferably, however, (z) is equal to one, two, three, four or five.

The carbon chain can be a simple, straight chain of carbon atoms. Simple, straight carbon chains are those in which each R<sup>1</sup> and R<sup>2</sup> is defined as hydrogen. In addition, the carbon chain may comprise one or more carbon-carbon double and/or  
 20 triple bonds. Moreover, the carbon chain can be singly branched wherein one of R<sup>1</sup> and R<sup>2</sup> is defined as an atom or group of atoms other than hydrogen, such as alkyl,

and all other  $R^1$  and  $R^2$  variables are hydrogen. Multiple branching is also envisioned wherein multiple instances of  $R^1$  and/or  $R^2$  are defined as an atom or group of atoms other than hydrogen (e.g., alkyl). It is preferred, however, that branched species include only a single branching point. In addition, it is preferred that the single branch point occurs at the carbon atom  $\alpha$  to (or immediately adjacent to) the "branching carbon atom" in the ortho ester functionality.

Optionally, a spacer moiety can be located between the carbon chain and the suitable leaving group. Exemplary ortho esters comprising such a spacer moiety comprise the following structure:

10



wherein:

15

$X^2$  is a spacer moiety and , (z), each  $R^1$ , each  $R^2$ , and are as previously defined.

20

The optional spacer moiety (i.e.,  $X^2$ ) in the ortho ester comprising a suitable leaving group is any atom or series of atoms separating the carbon chain of (z) atoms from the leaving group. Depending on the actual atom or atoms that make up this spacer moiety, the spacer moiety can be hydrolytically stable or hydrolytically unstable. Whether any specific moiety is hydrolytically stable or unstable can be determined by one of ordinary skill in the art or determined experimentally using routine experimentation. This optional spacer moiety  $X^2$  can be selected from the spacer moieties identified below with respect to X. In those instances where  $X^2$  appears within the same structure defined as comprising an X or  $X^1$ ,  $X^2$  can be the same or different.

25

It should be stressed that although the ortho ester comprising a suitable leaving group comprises a carbon chain of (z) atoms, the presence of the carbon chain is not necessary to provide a carboxylic acid. Consequently, when a

water-soluble polymer bearing a terminal carboxylic acid other than an alkanolic acid (e.g., a propanoic acid, butanoic acid, and so forth) is desired, the carbon chain is omitted and replaced by, for example, a spacer moiety or other group of atoms.

5 The ortho ester having a suitable leaving group can be prepared synthetically. For example, acyclic ortho esters can be prepared by obtaining an imino ester (also referred to as an "alkyl imidate") through, for example, a Pinner reaction. In this approach, an imino ester is formed via the addition of anhydrous hydrogen chloride gas to a mixture of a nitrile and an alcohol. Subsequent treatment of the imino ester with an alcohol yields the corresponding ortho ester.  
10 See, for example, Voss *et al.* (1983) *Helv. Chim. Acta.* 66:2294.

Cyclic ortho esters can be prepared via conversion of a hydroxyalkyloxetane to the corresponding carboxylic ester, which, following rearrangement, yields a bridged ortho ester. These and other approaches for preparing cyclic ortho esters are described in the literature. See, for example: Corey *et al.* (1983) *Tetrahedron Lett.* 24(50):5571-5574; Wipf *et al.* (1999) *Pure Appl. Chem.* 71(3):415-421; and  
15 Greene *et al.* PROTECTIVE GROUPS IN ORGANIC SYNTHESIS, 3rd ed., pp. 437-441, John Wiley & Sons, New York, NY (1999). The suitable leaving group is introduced in the ortho ester by including the leaving group in the reactant prior to formation of the ortho ester or by adding it subsequent to the formation of the ortho ester.  
20

In some cases, the ortho ester comprising a suitable leaving group is available commercially. For example, one commercially available ortho ester is trimethyl 4-bromoorthobutyrate available from Sigma-Aldrich Corporation of St. Louis, MO.

25

#### THE WATER-SOLUBLE POLYMER HAVING AT LEAST ONE HYDROXYL OR THIOL GROUP

Any water-soluble polymer having at least one hydroxyl or thiol group (to provide, for example, a water-soluble polymer having at least one alkoxide ion or  
30 thiolate ion, respectively) can be used in accordance with the invention and the

invention is not limited in this regard. Although water-soluble polymers bearing only a single hydroxyl or thiol can be used, polymers bearing two, three, four, five, six, seven, eight, nine, ten, eleven, twelve or more hydroxyl and/or thiol moieties can be used. Advantageously, as the number of hydroxyl or thiol moieties on the water-polymer segment increases, the number of available sites for providing carboxylic acid moieties increases. Nonlimiting examples of the upper limit of the number of hydroxyl and/or thiol moieties associated with the water-soluble polymer segment include 500, 100, 80 and 40.

The water-soluble polymer segment is preferably, although not necessarily, a poly(ethylene glycol) or "PEG" or a derivative thereof. It should be understood, however, that related polymers are also suited for use in the practice of this invention and that the use of the term "PEG" or "poly(ethylene glycol)" is intended to be inclusive and not exclusive in this respect. Consequently, the term "PEG" includes poly(ethylene glycol) in any of its linear, branched or multi-arm forms, including alkoxy PEG, bifunctional PEG, forked PEG, branched PEG, pendant PEG, or PEG with degradable linkages therein, to be more fully described below.

In one form useful in the present invention, free or non-bound PEG is a linear polymer terminated at each end with hydroxyl groups:



(m') typically ranges from zero to about 4,000, preferably about 20 to about 1,000.

The above polymer, alpha-,omega-dihydroxypoly(ethylene glycol), can be represented in brief form as HO-PEG-OH where it is understood that the -PEG- symbol can represent the following structural unit:



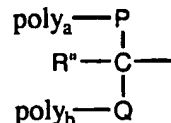
where (m') is as defined as above.

Another type of PEG useful in the present invention is methoxy-PEG-OH, or mPEG in brief, in which one terminus is the relatively inert methoxy group, while the other terminus is a hydroxyl group. The structure of mPEG is given below.



where (m') is as described above.

Multi-armed or branched PEG molecules, such as those described in U.S. Patent No. 5,932,462, can also be used as the PEG polymer. For example, PEG can have the structure:



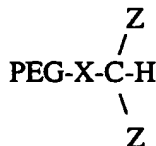
wherein:

poly<sub>a</sub> and poly<sub>b</sub> are PEG backbones (either the same or different), such as methoxy poly(ethylene glycol);

10 R'' is a nonreactive moiety, such as H, methyl or a PEG backbone; and

P and Q are nonreactive linkages. In a preferred embodiment, the branched PEG polymer is methoxy poly(ethylene glycol) disubstituted lysine.

In addition, the PEG can comprise a forked PEG. An example of a forked PEG is represented by the following structure:



wherein: X is a spacer moiety and each Z is an activated terminal group linked to CH by a chain of atoms of defined length. International Application No.

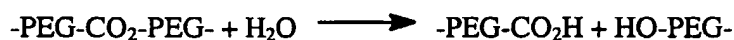
25 PCT/US99/05333, discloses various forked PEG structures capable of use in the present invention. The chain of atoms linking the Z functional groups to the branching carbon atom serve as a tethering group and may comprise, for example, alkyl chains, ether chains, ester chains, amide chains and combinations thereof.

The PEG polymer may comprise a pendant PEG molecule having reactive groups, such as carboxyl, covalently attached along the length of the PEG rather



than at the end of the PEG chain. The pendant reactive groups can be attached to the PEG directly or through a spacer moiety, such as an alkylene group.

In addition to the above-described forms of PEG, the polymer can also be prepared with one or more weak or degradable linkages in the polymer, including  
5 any of the above described polymers. For example, PEG can be prepared with ester linkages in the polymer that are subject to hydrolysis. As shown below, this hydrolysis results in cleavage of the polymer into fragments of lower molecular weight:



10 Other hydrolytically degradable linkages, useful as a degradable linkage within a polymer backbone, include carbonate linkages; imine linkages resulting, for example, from reaction of an amine and an aldehyde (see, e.g., Ouchi *et al.* (1997) *Polymer Preprints* 38(1):582-3); phosphate ester linkages formed, for example, by reacting an alcohol with a phosphate group; hydrazone linkages which  
15 are typically formed by reaction of a hydrazide and an aldehyde; acetal linkages that are typically formed by reaction between an aldehyde and an alcohol; ortho ester linkages that are, for example, formed by reaction between a formate and an alcohol; amide linkages formed by an amine group, e.g., at an end of a polymer such as PEG, and a carboxyl group of another PEG chain; urethane linkages formed  
20 from reaction of, e.g., a PEG with a terminal isocyanate group and a PEG alcohol; peptide linkages formed by an amine group, e.g., at an end of a polymer such as PEG, and a carboxyl group of a peptide; and oligonucleotide linkages formed by, for example, a phosphoramidite group, e.g., at the end of a polymer, and a 5' hydroxyl group of an oligonucleotide.

25 It is understood by those of ordinary skill in the art that the term poly(ethylene glycol) or PEG represents or includes all the above forms of PEG.

Many other polymers are also suitable for the invention. Polymers that are non-peptidic and water-soluble, with from 2 to about 300 termini, are particularly useful in the invention. Examples of suitable polymers include, but are not limited to, other poly(alkylene glycols), such as poly(propylene glycol) ("PPG"),  
30

copolymers of ethylene glycol and propylene glycol and the like, poly(olefinic alcohol), poly(vinylpyrrolidone), poly(hydroxyalkylmethacrylamide), poly(hydroxyalkylmethacrylate), poly(saccharides), poly( $\alpha$ -hydroxy acid), poly(vinyl alcohol), polyphosphazene, polyoxazoline, poly(N-acryloylmorpholine),  
5 such as described in U.S. Patent No. 5,629,384, and copolymers, terpolymers, and mixtures thereof. These polymers may be linear, or may be in any of the above-described forms (e.g., branched, forked, and the like).

Although the nominal average molecular weight of the water-soluble polymer can vary, the nominal average molecular weight will typically be in one or  
10 more of the following ranges: about 100 Daltons to about 100,000 Daltons; from about 500 Daltons to about 80,000 Daltons; from about 1,000 Daltons to about 50,000 Daltons; from about 2,000 Daltons to about 25,000 Daltons; from about 5,000 Daltons to about 20,000 Daltons. Exemplary nominal average molecular weights for the water-soluble polymer segment include about 1,000 Daltons, about  
15 5,000 Daltons, about 10,000 Daltons, about 15,000 Daltons, about 20,000 Daltons, about 25,000 Daltons, and about 30,000 Daltons.

The PEG and other water-soluble polymers as described herein are typically considered to be biocompatible and non-immunogenic. With respect to biocompatibility, a substance is considered biocompatible if the beneficial effects  
20 associated with use of the substance alone or with another substance (e.g., active agent) in connection with living tissues (e.g., administration to a patient) outweighs any deleterious effects as evaluated by a clinician, e.g., a physician. With respect to non-immunogenicity, a substance is considered non-immunogenic if use of the substance alone or with another substance in connection with living tissues does not  
25 produce an immune response (e.g., the formation of antibodies) or, if an immune response is produced, that such a response is not deemed clinically significant or important as evaluated by a clinician. It is particularly preferred that the polymers described herein as well as conjugates of active agents and the water-soluble polymers and segments described herein are biocompatible and non-immunogenic.

30 Those of ordinary skill in the art will recognize that the foregoing discussion concerning substantially water-soluble polymers is by no means exhaustive and is

merely illustrative, and that all polymeric materials having the qualities described above are contemplated. As used herein, the "term water-soluble polymer" generally refers to an entire molecule, which can comprise functional groups such as hydroxyl groups, thiol groups, ortho ester functionalities and so forth. The term  
 5 water-soluble polymer segment is generally reserved for use in discussing specific molecular structures wherein a polymer or portion thereof is but one part of the overall molecular structure.

An example of a preferred water-soluble polymer bearing a hydroxyl or thiol moiety comprises the following structure:

10



wherein POLY is a water-soluble polymer segment;

(a) is zero or one;

15

X, when present, is a spacer moiety; and

Y is O or S.

20

Recognizing certain instances wherein a water-soluble polymer segment (i.e., a "POLY") is defined as containing a hydroxyl or thiol moiety (e.g.,  $\text{CH}_3\text{O}-(\text{CH}_2\text{CH}_2\text{O})_m\text{-H}$  or  $\text{CH}_3\text{O}-(\text{CH}_2\text{CH}_2\text{O})_m\text{-(CH}_2\text{CH}_2\text{S)-H}$ , respectively), the "-YH" moiety of Formula II is understood to represent the hydroxyl or thiol moiety of "POLY" and not the irrational interpretation of, for example, " $\text{CH}_3\text{O}-(\text{CH}_2\text{CH}_2\text{O})_m\text{-H-YH}$ ." Alternatively,  $\text{CH}_3\text{O}-(\text{CH}_2\text{CH}_2\text{O})_m\text{-H}$ , for example, is encompassed by Formula II when POLY is defined as " $\text{CH}_3\text{O}-(\text{CH}_2\text{CH}_2\text{O})_m\text{-}$ " (a) is one, X is "- $\text{CH}_2\text{CH}_2\text{-}$ " and Y is "-O-". Thus, given the possibility that there can be more than  
 25 a single way for any individual molecule to be encompassed by a given formula, due consideration must be given in order to determine whether a molecule in question is or is not encompassed by a given formula.

A particular preferred water-soluble segment bearing a single hydroxyl group comprises the following structure:



wherein:

(m) is from 2 to 4000; and

5  $R^5$  is an end-capping group such as H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl. It is especially preferred that  $R^5$  is a lower alkyl such as methyl, although benzyl and other end-capping groups known to those of skill in the art can also be used.

10 For purposes of the present disclosure, however, a series of atoms is not a spacer moiety when the series of atoms is immediately adjacent to a polymer and the series of atoms is but another monomer such that the proposed spacer moiety would represent a mere extension of the polymer chain. For example, given the partial structure "POLY-X," and POLY is defined as " $CH_3O(CH_2CH_2O)_m$ ," wherein (m) is 2 to 4000 and X is defined as a spacer moiety, the spacer moiety  
15 cannot be defined as " $-CH_2CH_2O-$ " since such a definition would merely represent an extension of the polymer. In such a case, however, an acceptable spacer moiety could be defined as " $-CH_2CH_2-$ ."

Exemplary spacer moieties include, but are not limited to,  $-C(O)-$ ,  
 $-C(O)-NH-$ ,  $-NH-C(O)-NH-$ ,  $-O-C(O)-NH-$ ,  $-C(S)-$ ,  $-CH_2-$ ,  $-CH_2-CH_2-$ ,  
 20  $-CH_2-CH_2-CH_2-$ ,  $-CH_2-CH_2-CH_2-CH_2-$ ,  $-O-CH_2-$ ,  $-CH_2-O-$ ,  $-O-CH_2-CH_2-$ ,  
 $-CH_2-O-CH_2-$ ,  $-CH_2-CH_2-O-$ ,  $-O-CH_2-CH_2-CH_2-$ ,  $-CH_2-O-CH_2-CH_2-$ ,  
 $-CH_2-CH_2-O-CH_2-$ ,  $-CH_2-CH_2-CH_2-O-$ ,  $-O-CH_2-CH_2-CH_2-CH_2-$ ,  
 $-CH_2-O-CH_2-CH_2-CH_2-$ ,  $-CH_2-CH_2-O-CH_2-CH_2-$ ,  $-CH_2-CH_2-CH_2-O-CH_2-$ ,  
 $-CH_2-CH_2-CH_2-CH_2-O-$ ,  $-C(O)-NH-CH_2-$ ,  $-C(O)-NH-CH_2-CH_2-$ ,  
 25  $-CH_2-C(O)-NH-CH_2-$ ,  $-CH_2-CH_2-C(O)-NH-$ ,  $-C(O)-NH-CH_2-CH_2-CH_2-$ ,  
 $-CH_2-C(O)-NH-CH_2-CH_2-$ ,  $-CH_2-CH_2-C(O)-NH-CH_2-$ ,  $-CH_2-CH_2-CH_2-C(O)-NH-$ ,  
 $-C(O)-NH-CH_2-CH_2-CH_2-CH_2-$ ,  $-CH_2-C(O)-NH-CH_2-CH_2-CH_2-$ ,  
 $-CH_2-CH_2-C(O)-NH-CH_2-CH_2-$ ,  $-CH_2-CH_2-CH_2-C(O)-NH-CH_2-$ ,  
 $-CH_2-CH_2-CH_2-C(O)-NH-CH_2-CH_2-$ ,  $-CH_2-CH_2-CH_2-CH_2-C(O)-NH-$ ,  
 30  $-C(O)-O-CH_2-$ ,  $-CH_2-C(O)-O-CH_2-$ ,  $-CH_2-CH_2-C(O)-O-CH_2-$ ,  $-C(O)-O-CH_2-CH_2-$ ,

-NH-C(O)-CH<sub>2</sub>-, -CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-,  
 -NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -C(O)-NH-CH<sub>2</sub>-, -C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-, -O-C(O)-NH-CH<sub>2</sub>-, -O-C(O)-NH-CH<sub>2</sub>-  
 CH<sub>2</sub>-, -NH-CH<sub>2</sub>-, -NH-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-NH-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-NH-CH<sub>2</sub>-, -C(O)-  
 5 CH<sub>2</sub>-, -C(O)-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-C(O)-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-,  
 10 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -O-C(O)-NH-[CH<sub>2</sub>]<sub>h</sub>-(OCH<sub>2</sub>CH<sub>2</sub>)<sub>j</sub>-, bivalent cycloalkyl group, -O-, -S-, an amino  
 acid, -N(R<sup>6</sup>)-, and combinations of two or more of any of the foregoing, wherein R<sup>6</sup>  
 is H or an organic radical selected from the group consisting of alkyl, substituted  
 alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl and substituted  
 15 aryl, (h) is zero to six, and (j) is zero to 20. Other specific spacer moieties have the  
 following structures: -C(O)-NH-(CH<sub>2</sub>)<sub>1-6</sub>-NH-C(O)-, -NH-C(O)-NH-(CH<sub>2</sub>)<sub>1-6</sub>-  
 NH-C(O)-, and -O-C(O)-NH-(CH<sub>2</sub>)<sub>1-6</sub>-NH-C(O)-, wherein the subscript values  
 following each methylene indicate the number of methylenes contained in the  
 structure, e.g., (CH<sub>2</sub>)<sub>1-6</sub> means that the structure can contain 1, 2, 3, 4, 5 or 6  
 20 methylenes.

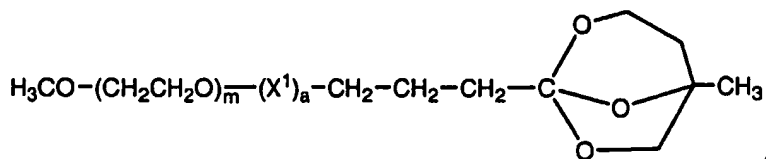
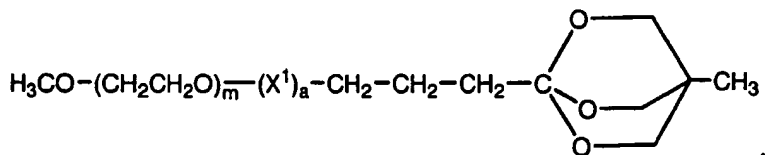
In the present context of an amino acid being included in the structures  
 provided herein, it should be remembered that the amino acid is connected to the  
 rest of the structure via one, two, three or more sites. For example, a spacer moiety  
 can result when an amino acid is attached to the rest of the molecule via two  
 25 covalent attachments. In addition, a branching structure can result when an amino  
 acid is attached to the rest of the molecule via three sites. Thus, the amino acid  
 structure necessarily changes somewhat due to the presence of one or more covalent  
 attachments (e.g., removal of a hydrogen atom from the amino acid in order to  
 accommodate a covalent linkage). Consequently, reference to an "amino acid"  
 30 therefore includes the amino acid containing one or more linkages to other atoms.  
 The amino acid can be selected from the group consisting of alanine, arginine,  
 asparagines, aspartic acid, cysteine, glutamic acid, glutamine, glycine, histidine,

isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, and valine. Both the D and L forms of the amino acids are contemplated.

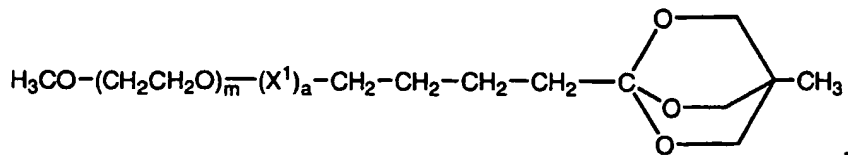
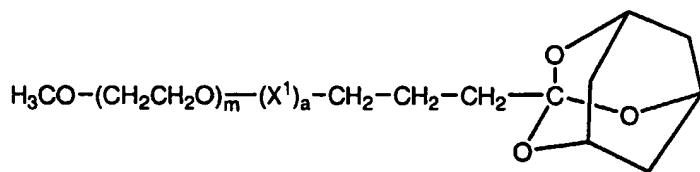
## 5 THE ORTHO ESTER OF A WATER-SOLUBLE POLYMER

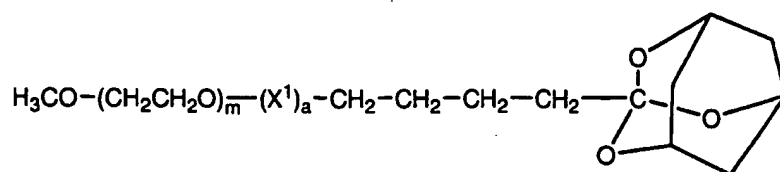
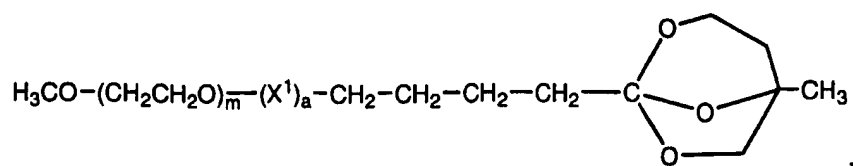
The present invention provides for water-soluble polymers comprising an ortho ester functionality. As described above, both acyclic and cyclic forms of the ortho ester functionality are included. Exemplary cyclic ortho esters of water-soluble polymers of the invention are shown below:

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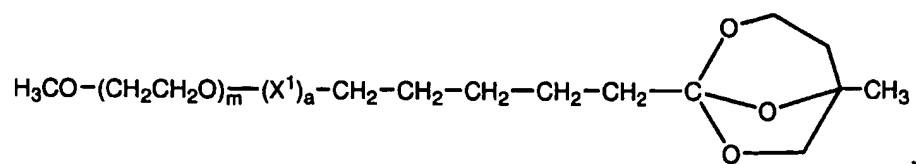
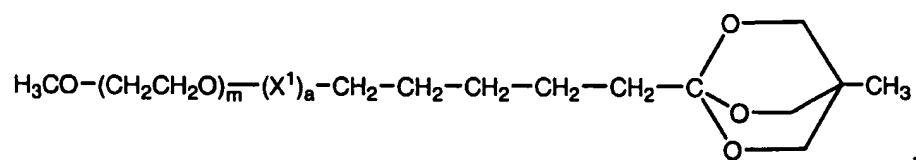


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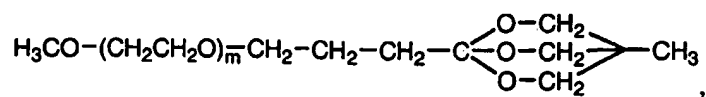
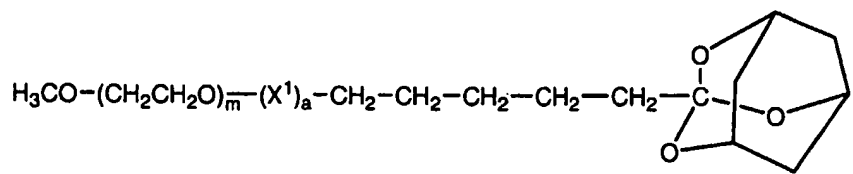


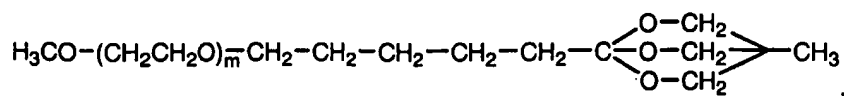
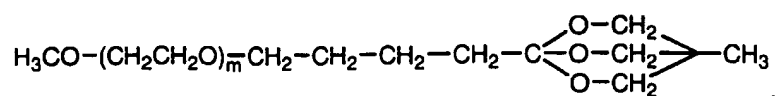


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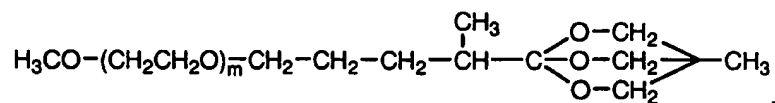
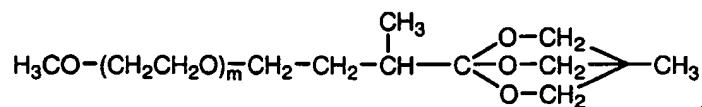


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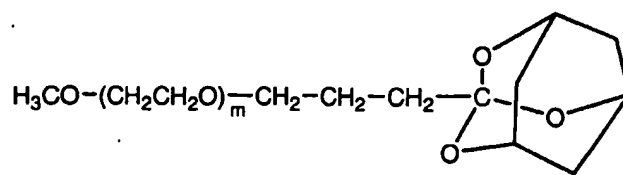
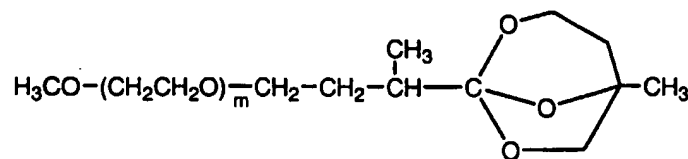
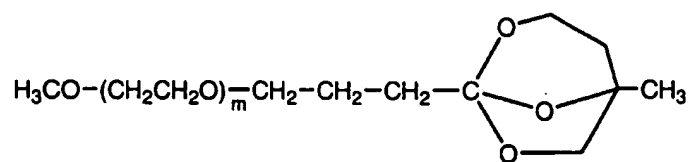
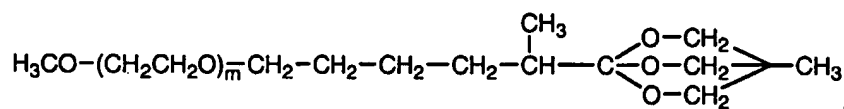




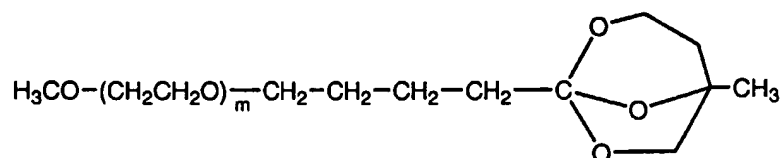
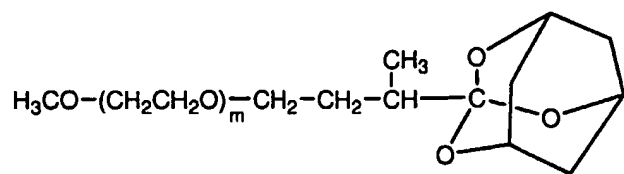
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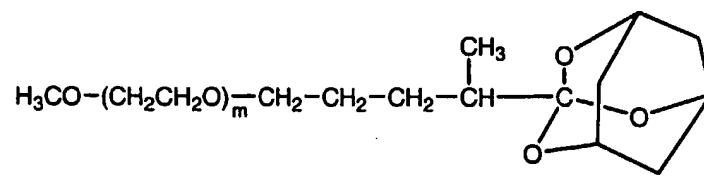
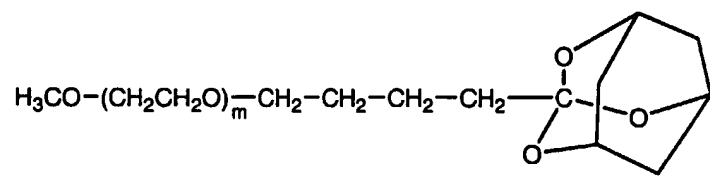
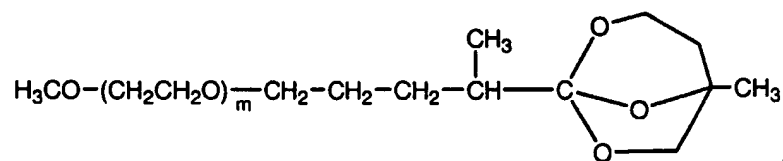
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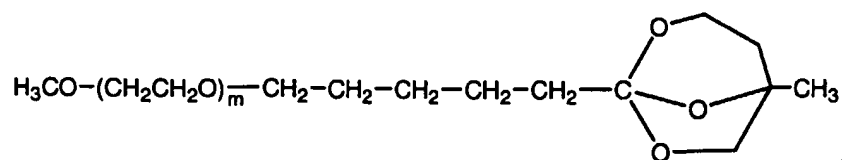


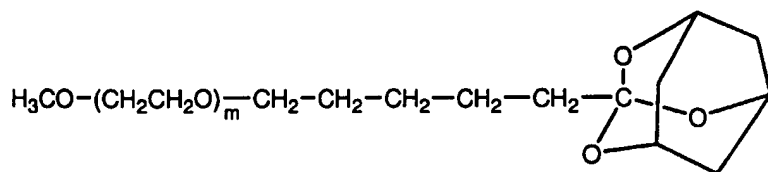
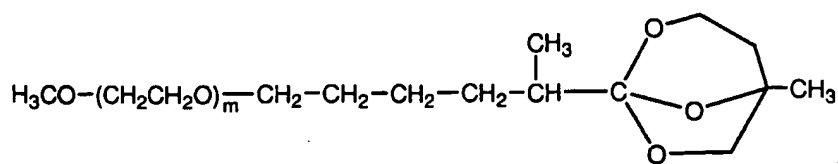


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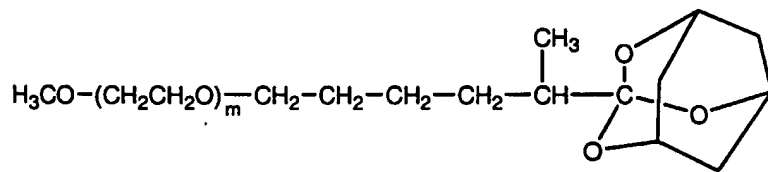


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and



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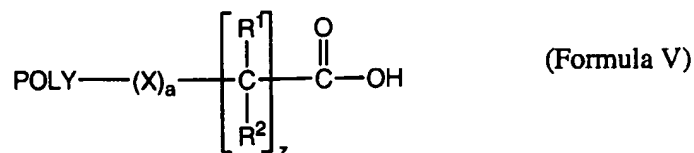
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wherein (m) is 2 to 4000, (a) is zero or one, and  $\text{X}^1$ , when present, is a spacer moiety. Of course, other water-soluble polymers comprising an ortho ester moiety are also possible and in accordance with the present invention.

#### THE WATER-SOLUBLE POLYMER BEARING A TERMINAL CARBOXYLIC ACID OR ESTER THEREOF

15 In accordance with the present methods, any number of polymers bearing a terminal carboxylic acid or ester thereof can be prepared and the invention is not limited in this regard. Consequently, the invention includes carboxylic acids, such as alkanolic acids, and the corresponding esters of a polymer formed by a method as provided herein.

20 With respect to alkanolic acids then, the invention provides for alkanolic acids comprising the following structure:



wherein:

5 POLY is a water-soluble polymer segment;

(a) is either zero or one;

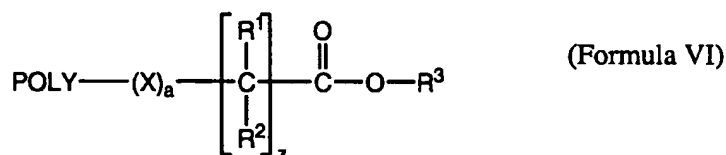
X, when present, is a spacer moiety;

(z) is an integer from 1 to 24;

10 R<sup>1</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

R<sup>2</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.

15 In addition, esters of the water-soluble polymer bearing a terminal carboxylic acid are provided. For example, the corresponding esters of the carboxylic acids of Formula V preferably have the following structure:



20 wherein POLY, (a), X, when present, (z), each R<sup>1</sup>, and each R<sup>2</sup> are as previously defined, and R<sup>3</sup> is an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl. In order to refer to polymers bearing a terminal carboxylic acid or ester thereof, R<sup>3</sup> can conveniently be defined as H (thereby referring to the acid) or an organic radical selected from the group consisting of alkyl, substituted alkyl,

25

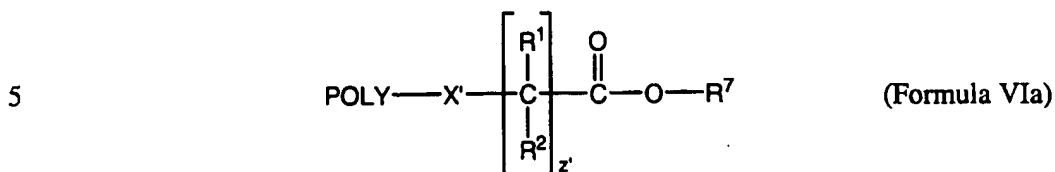
alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl (thereby referring to a corresponding ester). The carboxylic acids and esters provided herein include sulfur-substituted versions, e.g.,  $-C(O)-S-R^3$ , as well.

For any given carboxylic acid, the corresponding ester can be formed using conventional techniques. For example, the water-soluble polymer bearing a terminal carboxylic acid can undergo acid-catalyzed condensation with an alcohol, thereby providing the corresponding ester. One approach to accomplish this is to use the method commonly referred to as a Fischer esterification reaction. Other techniques for forming a desired ester are known by those of ordinary skill in the art.

In addition, the water-soluble polymer bearing a terminal carboxylic acid can be modified to form useful reactive derivatives of alkanolic acids using methodology known in the art. For example, the carboxylic acid can be further derivatized to form acyl halides, acyl pseudohalides, such as acyl cyanide, acyl isocyanate, and acyl azide, neutral salts, such as alkali metal or alkaline-earth metal salts (e.g. calcium, sodium, and barium salts), esters, anhydrides, amides, imides, hydrazides, and the like. In a preferred embodiment, the carboxylic acid is esterified to form an N-succinimidyl ester, *o*-, *m*-, or *p*-nitrophenyl ester, 1-benzotriazolyl ester, imidazolyl ester, or N-sulfosuccinimidyl ester. For example, the carboxylic acid can be converted into the corresponding N-succinimidyl ester by reacting the carboxylic acid with dicyclohexyl carbodiimide (DCC) or diisopropyl carbodiimide (DIC) in the presence of a base.

Particularly preferred polymers bearing a terminal carboxylic acid moiety, however, are those wherein the carboxylic acid moiety forms part of an alkanolic acid. In this respect, carbon chains of four or more carbon atoms (including the carbonyl carbon) that terminate in a carboxylic acid or nonaromatic ester are preferred. It is preferred that the water-soluble polymer segment is covalently attached through one or more atoms to the distal carbon (with respect to the carbonyl carbon) in the carbon chain that is at least four carbon atoms. Moreover, when the water-soluble polymer segment is covalently attached through only one

atom, the one atom is not O or S. Such polymers can be structurally defined as follows:



wherein:

POLY is a water-soluble polymer segment;

10 X' is a spacer moiety with the proviso that when the spacer moiety is only one atom, the one atom is not O or S;

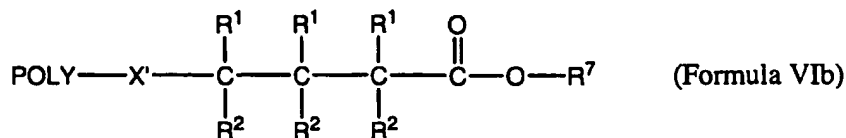
(z') is an integer from 3 to 21;

R<sup>1</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

15 R<sup>2</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

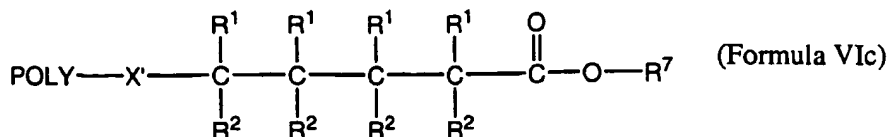
R<sup>7</sup> is H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, and substituted alkynyl.

20 Preferably, (z') is three, four, or five. When (z') is equal to three, the polymer of Formula VIa is comprised of the following structure:



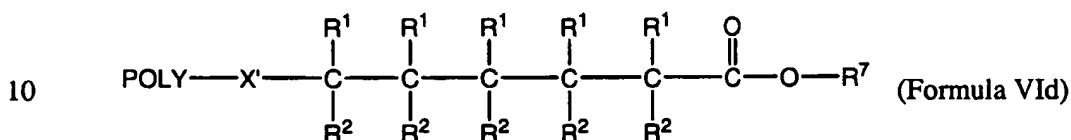
25 wherein POLY, X', each R<sup>1</sup>, each R<sup>2</sup> and R<sup>7</sup> are as previously defined.

When (z') is equal to four, the polymer of Formula VIa is comprised of the following structure



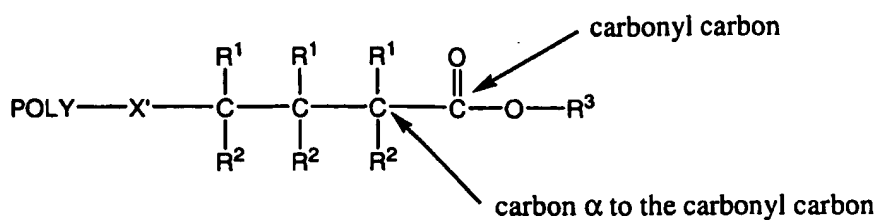
5 wherein POLY, X', each R<sup>1</sup>, each R<sup>2</sup> and R<sup>7</sup> are as previously defined.

When (z') is equal to five, the polymer of Formula VIa is comprised of the following structure:



wherein POLY, X', each R<sup>1</sup>, each R<sup>2</sup> and R<sup>7</sup> are as previously defined.

In each of these cases, R<sup>7</sup> is hydrogen when the carboxylic acid is desired. With respect to R<sup>1</sup> and R<sup>2</sup>, in some instances, each R<sup>1</sup> and R<sup>2</sup> is hydrogen. In other instances, however, the R<sup>1</sup> attached to the carbon α to the carbonyl carbon is alkyl (e.g., methyl, ethyl, *n*-propyl, isopropyl, *n*-butyl, *sec*-butyl, isobutyl, and *tert*-butyl) and all other R<sup>1</sup> variables are H and all R<sup>2</sup> variables are hydrogen. As is known by those of ordinary skill in the art, the "carbon α to the carbonyl" indicates the carbon atom directly attached to the carbonyl carbon. For illustrative purposes, the "carbon α to the carbonyl carbon" as well as the "carbonyl carbon" are labeled in the following structure:

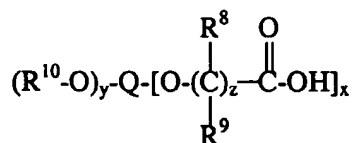


Other arrangements are also envisioned wherein R<sup>1</sup> attached to the carbon atom β, γ or δ, to the carbonyl carbon is an organic radical. In addition, combinations in which two or more R<sup>1</sup> substituents are defined as an organic radical are possible. These same substitutions apply to the corresponding ortho ester polymers and reagents.

When the carbon α to the carbonyl carbon bears an organic radical (e.g., methyl), the resulting polymer may comprise a chiral center. Specific chirality, however, is not explicitly illustrated herein with respect to any compound or structure comprising one or more chiral centers and the invention is intended to encompass both the isomerically pure forms of the compound or structure as well as diastereomeric mixtures, including a racemic mixture, thereof.

X' is the same as X, as defined above, with the exception that X' is not O or S.

The carboxylic acids as provided herein may also be defined through the following formula:



wherein:

R<sup>10</sup> is H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

Q is a residue of a polyhydric alcohol having x+y hydroxyl groups;

R<sup>8</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

$R^9$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

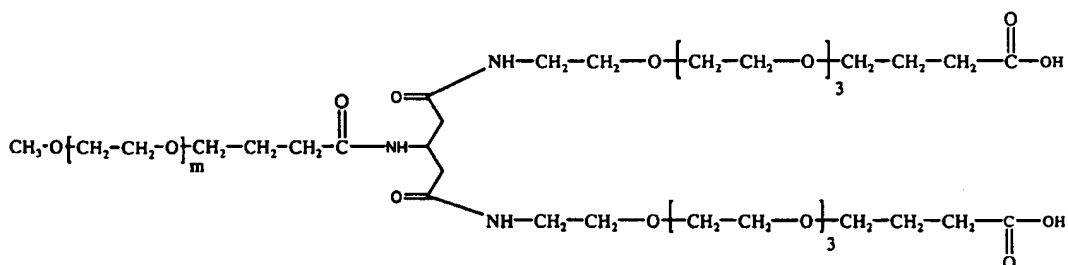
(x) is 1 to 20, preferably 2, 3, 4, 5, or 6;

5 (y) is 1 to 20; and

(z) is 1 to 24, preferably from 4 to 20.

Representative Q moieties include the following: propylene glycol, glycerine, sorbitol, pentaerythritol, dipentaerythritol, dihydroxycyclohexane, glucose, galactose, mannose, fructose, mannose, lactose, sucrose, amylose, as well as other  
10 sugars.

An example preferred polymer bearing two terminal carboxylic acid moieties (a "forked" structure) comprises the following:



15

wherein (m) is from 2 to 4000. Preferably, however, the weight average molecular weight for the water-soluble polymer segment is from about 5,000 Daltons to about 40,000 Daltons, more preferably from about 20,000 Daltons to about 30,000  
20 Daltons, with a molecular weight of about 20,000 Daltons being most preferred.

#### STORAGE CONDITIONS GENERALLY

The polymers bearing a terminal carboxylic acid or ester thereof, as well as any intermediates in their formation (e.g., ortho esters of water-soluble polymers),



can be stored under an inert atmosphere, such as under argon or under nitrogen. In this way, potentially degradative processes associated with, for example, atmospheric oxygen, are avoided or reduced entirely. In some cases, to avoid oxidative degradation, antioxidants, such as butylated hydroxyl toluene (BHT), can be added to the final product prior to storage. In addition, it is preferred to minimize the amount moisture associated with the storage conditions to reduce potentially damaging reactions associated with water. Moreover, it is preferred to keep the storage conditions dark in order to prevent certain degradative processes that involve light. Thus, preferred storage conditions include one or more of the following: storage under dry argon or another dry inert gas; storage at temperatures below about -15 °C; storage in the absence of light; and storage with a suitable amount (e.g., about 50-500 parts per million) of an antioxidant such as BHT.

#### CONJUGATION METHOD

The above-described polymers bearing a terminal carboxylic acid, optionally in an activated form, are useful for conjugation to biologically active agents or surfaces comprising at least one group suitable for reaction with a carboxylic acid or the optional activated form. Exemplary groups suitable for reaction with a carboxylic acid include amino groups (e.g., primary amines), hydrazines, hydrazides, and alcohols. Often, the polymer bearing a terminal carboxylic acid moiety can be conjugated directly to the active agent or surface. Sometimes, however, it is necessary to form an "activated" version of the carboxylic acid in order to enhance reactivity to the biologically active agent or surface. Methods for activating carboxylic acids are known in the art and include, for example, dissolving the water-soluble polymer bearing a terminal carboxylic acid in methylene chloride and subsequently adding N-hydroxysuccinimide and N,N-dicyclohexylcarbodiimide (DCC) to form an activated N-succinimidyl ester version of the carboxylic acid. Other approaches for activating a carboxylic acid are known to those of ordinary skill in the art.

Typically, the water-soluble polymer bearing the carboxylic acid or ester thereof is added to the active agent or surface at an equimolar amount (with respect to the desired number of groups suitable for reaction with the carboxylic acid or

ester thereof) or at a molar excess. For example, the polymer can be added to the target active agent at a molar ratio of about 1:1 (polymer:active agent), 1.5:1, 2:1, 3:1, 4:1, 5:1, 6:1, 8:1, or 10:1. The conjugation reaction is allowed to proceed until substantially no further conjugation occurs, which can generally be determined by monitoring the progress of the reaction over time. Progress of the reaction can be monitored by withdrawing aliquots from the reaction mixture at various time points and analyzing the reaction mixture by SDS-PAGE or MALDI-TOF mass spectrometry or any other suitable analytical method. Once a plateau is reached with respect to the amount of conjugate formed or the amount of unconjugated polymer remaining, the reaction is assumed to be complete. Typically, the conjugation reaction takes anywhere from minutes to several hours (e.g., from 5 minutes to 24 hours or more). The resulting product mixture is preferably, but not necessarily purified, to separate out excess reagents, unconjugated reactants (e.g., active agent) undesired multi-conjugated species, and free or unreacted polymer. The resulting conjugates can then be further characterized using analytical methods such as MALDI, capillary electrophoresis, gel electrophoresis, and/or chromatography.

#### CHARACTERIZATION/SEPARATION

With respect to polymer-active agent conjugates, the conjugates can be purified to obtain/isolate different conjugated species. Alternatively, and more preferably for lower molecular weight (e.g., less than about 20 kiloDaltons, more preferably less than about 10 kiloDaltons) polymers, the product mixture can be purified to obtain the distribution of water-soluble polymer segments per active agent. For example, the product mixture can be purified to obtain an average of anywhere from one to five PEGs per active agent (e.g., protein), typically an average of about 3 PEGs per active agent (e.g., protein). The strategy for purification of the final conjugate reaction mixture will depend upon a number of factors, including, for example, the molecular weight of the polymer employed, the particular active agent, the desired dosing regimen, and the residual activity and *in vivo* properties of the individual conjugate(s).

If desired, conjugates having different molecular weights can be isolated using gel filtration chromatography. That is to say, gel filtration chromatography is used to fractionate differently numbered polymer-to-active agent ratios (e.g., 1-mer, 2-mer, 3-mer, and so forth, wherein "1-mer" indicates 1 polymer to active agent, "2-mer" indicates two polymers to active agent, and so on) on the basis of their differing molecular weights (where the difference corresponds essentially to the average molecular weight of the water-soluble polymer segments). For example, in an exemplary reaction where a 100 kDa protein is randomly conjugated to a PEG alkanolic acid having a molecular weight of about 20 kDa, the resulting reaction mixture will likely contain unmodified protein (MW 100 kDa), mono-pegylated protein (MW 120 kDa), di-pegylated protein (MW 140 kDa), and so forth. While this approach can be used to separate PEG and other polymer conjugates having different molecular weights, this approach is generally ineffective for separating positional isomers having different polymer attachment sites within the protein. For example, gel filtration chromatography can be used to separate from each other mixtures of PEG 1-mers, 2-mers, 3-mers, and so forth, although each of the recovered PEG-mer compositions may contain PEGs attached to different reactive amino groups (e.g., lysine residues) within the active agent.

Gel filtration columns suitable for carrying out this type of separation include Superdex™ and Sephadex™ columns available from Amersham Biosciences (Piscataway, NJ). Selection of a particular column will depend upon the desired fractionation range desired. Elution is generally carried out using a suitable buffer, such as phosphate, acetate, or the like. The collected fractions may be analyzed by a number of different methods, for example, (i) optical density (OD) at 280 nm for protein content, (ii) bovine serum albumin (BSA) protein analysis, (iii) iodine testing for PEG content [Sims *et al.* (1980) *Anal. Biochem.*, 107:60-63], and (iv) sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS PAGE), followed by staining with barium iodide.

Separation of positional isomers is carried out by reverse phase chromatography using a reverse phase-high performance liquid chromatography (RP-HPLC) C18 column (Amersham Biosciences or Vydac) or by ion exchange chromatography using an ion exchange column, e.g., a Sepharose™ ion exchange

# United States Court of Appeals for the Federal Circuit

04-1291

ON-LINE TECHNOLOGIES, INC.,

Plaintiff-Appellant,

v.

BODENSEEWERK PERKIN-ELMER GMBH,  
PERKIN-ELMER CORP., PERKIN-ELMER INC.,  
SICK UPA GMBH, and SICK, A.G.,

Defendants-Appellees.

Gabriel Berg, Berg & Androphy, of New York, New York, argued for plaintiff-appellant.

Edward T. Colbert, Kenyon & Kenyon, of Washington, DC, argued for defendants-appellees. With him on the brief was C. Kyle Musgrove. Of counsel on the brief were Francis H. Morrison III and Jonathan B. Tropp, Day, Berry & Howard LLP, of Hartford, Connecticut.

Appealed from: United States District Court for the District of Connecticut

Judge Janet Bond Arterton

# United States Court of Appeals for the Federal Circuit

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Defendants-Appellees.

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DECIDED: October 13, 2004

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Before MICHEL, Circuit Judge, ARCHER, Senior Circuit Judge, and BRYSON, Circuit Judge.

BRYSON, Circuit Judge.

The dispute in this case involves a device known as a long-path gas cell, which is used in an infrared spectrometer to determine the composition of gases such as emissions from industrial plants. The spectrometer captures the gas to be tested and directs a beam of infrared light through the chamber containing the gas. After the light has passed through the chamber, a detector measures the absorption of the light, from which the properties of the gas can be determined.

It has long been understood in the art that lengthening the light path in the gas cell chamber can result in a more accurate absorption reading. One problem

encountered in long-path gas cells, however, was that over the long path created by multiple reflections of the light beam within the chamber, the quality of the beam would become degraded, primarily because of astigmatism induced by the mirrors used in the system. Astigmatism is an optical aberration created when an optical element or system has a different focal length in each of two orthogonal planes. K.D. Moeller, Optics 448 (1988); H.P. Brueggemann, Conic Mirrors 15 (1968).

In 1995, appellant On-Line Technologies, Inc., obtained a patent, U.S. Patent No. 5,440,143 ("the '143 patent"), on a method for increasing the length of the light path in a gas cell while correcting for astigmatism and thereby reducing the diffusion of the beam of light. On-Line subsequently brought an action in the United States District Court for the District of Connecticut against a group of related parties, Bodenseewerk Perkin-Elmer GmbH; Perkin-Elmer Corp.; Perkin-Elmer Inc.; Sick UPA GmbH; and Sick, A.G. (collectively, "Perkin-Elmer"). On-Line Techs., Inc. v. Bodenseewerk Perkin-Elmer GmbH, No. 3:99CV2146 (D. Conn. filed Nov. 3, 1999).

In its complaint, On-Line alleged that Perkin-Elmer had made, used, and sold a device that infringed the '143 patent. In addition, On-Line asserted several state law claims, including misappropriation of trade secrets, violation of the state law of unfair competition, breach of contract, and fraud. In support of the state law claims, On-Line alleged that, pursuant to a nondisclosure agreement, it had revealed its gas cell design to Perkin-Elmer scientists in anticipation of a possible business arrangement between the companies relating to On-Line's device. Rather than pursuing a joint enterprise, however, Perkin-Elmer allegedly copied what it had learned from On-Line and incorporated the disclosed technology into its commercial product, thus breaching the

nondisclosure agreement and violating the state law prohibitions against unfair competition, theft of trade secrets, and fraud.

After discovery, the district court disposed of the patent infringement claim by granting summary judgment of noninfringement. The court also granted summary judgment in favor of Perkin-Elmer on all of On-Line's state law claims, finding that On-Line had failed to show that there was a disputed issue of material fact with respect to any of those claims. Finally, the court dismissed one of the defendants, Sick, A.G., for lack of personal jurisdiction. On-Line appeals all three aspects of the judgment.

I

The district court's grant of summary judgment of noninfringement as to claim 1 of the '143 patent was premised on the court's claim construction. On-Line contends that the district court erred in construing the claim and therefore erred in entering summary judgment.

Claim 1 of the '143 patent recites as follows (emphasis added):

A folded-path radiation absorption gas cell comprising: an enclosure having first and second ends, and defining a substantially closed chamber therewithin; spaced input radiation and output radiation windows formed through said first end of said enclosure and aligned on a first axis; a concave reflective field surface extending at least partially between said windows at said first end of said enclosure; a pair of substantially spherical, concave reflective objective surfaces at said second end of said enclosure disposed in confronting relationship to said field surface, said objective surfaces being aligned side-by-side on an axis

parallel to said first axis and in optical registry with said windows, at least one of said objective surfaces having a cylindrical component added thereto to increase coincidence of foci in two orthogonal planes, thereby to maximize the energy throughput characteristic of said cell; and means for the introduction and withdrawal of gas into and from said chamber of said enclosure.

The invention to which claim 1 is directed is an improvement on a type of gas cell known as a "White cell." A White cell uses several mirrors that are aligned to make the light follow a long path as it passes through the test chamber. In the invention, two mirrors are placed side by side at the opposite end of the main chamber from a third mirror. A beam of light enters the chamber and is repeatedly reflected off the three mirrors until it reaches an exit point. Because the mirrors reflect the light beam back and forth across the chamber multiple times, the path of the beam is much longer than the distance from one end of the chamber to the other.

The '143 patent sought to address the problem of astigmatic diffusion of the light beam passing through the cell. The solution proposed by the '143 patent was to shape the secondary mirrors in a manner that would counteract the astigmatism induced by reflections from the spherical mirrors used in White cells and thus keep the beam of light focused during its passage through the cell. '143 patent, col. 4, ll. 52-62. To achieve that purpose, each claim of the '143 patent required the mirrors to have "substantially spherical, concave reflective objective surfaces . . . at least one of said objective surfaces having a cylindrical component added thereto to increase



coincidence of foci in two orthogonal planes . . . .” Id., col. 5, ll. 44-52; col. 6, ll. 14-22, 40-48.

On-Line asserted that Perkin-Elmer’s commercial long-path gas cells infringed claim 1 of the ’143 patent. In particular, On-Line contended that Perkin-Elmer’s cells used objective mirrors of the sort recited in the claim to correct for astigmatism. In the district court, Perkin-Elmer did not dispute that its accused gas cells used objective mirrors shaped to correct for astigmatism. Perkin-Elmer argued, however, that its objective mirrors had toroidal surfaces, not “substantially spherical” surfaces “having a cylindrical component added thereto,” as required by claim 1 of the ’143 patent. For that reason, Perkin-Elmer argued, its gas cells were not within the scope of the patent, either literally or under the doctrine of equivalents. In essence, Perkin-Elmer’s argument was that a toroidal surface is different from a substantially spherical surface with a cylindrical component added to it. Because On-Line not only did not claim toroidal mirror surfaces but specifically omitted them from its claims, Perkin-Elmer contended that On-Line had dedicated surfaces of that shape to the public. The district court agreed with Perkin-Elmer and held that Perkin-Elmer’s toroidal surface was not covered by the ’143 patent.

In explaining its claim construction ruling, the district court noted that the specification described the contour of the spherical objective mirrors as “approach[ing] toroidal.” ’143 patent, col. 4, ll. 8-12. The court stated that “[b]ecause mirrors with a contour which only ‘approaches toroidal’ cannot be said to be actual toroidal mirrors, toroidal objective mirrors are not spherical objective mirrors with cylindrical corrections.” In support of that conclusion, the court cited extrinsic evidence, including testimony from

the inventors, which the court characterized as establishing that “spherical objective mirrors with cylindrical corrections are not the same as toroidal objective mirrors.” Because the court concluded that the claim language excluded toroidal surfaces, the court held that Perkin-Elmer’s gas cells did not literally infringe claim 1 of the ’143 patent. Moreover, because the court concluded that toroidal surfaces were disclosed but not claimed in the ’143 patent, the court invoked the principle that a patentee’s disclosure of unclaimed subject matter bars application of the doctrine of equivalents to that subject matter and held that On-Line could not rely on the doctrine of equivalents to reach toroidal mirrors such as Perkin-Elmer’s.

On appeal, On-Line contends that the district court erred in ruling that objective mirrors having a toroidal surface are not within the scope of claim 1 of the ’143 patent. We agree with On-Line that, properly construed, the reference to a “substantially spherical, concave reflective surface . . . having a cylindrical component added thereto to increase coincidence of foci in two orthogonal planes” defines a set of curved surfaces that includes a toroidal surface. We reach that conclusion because the specification makes clear that the claim language referring to spherical surfaces with cylindrical components includes toroidal surfaces.

A toroidal (or toric) surface is defined as a surface that is “generated if an arc is rotated about an axis which lies in the same plane as the arc, but which does not pass through its centre of curvature.” M. Jolie, The Principles of Ophthalmic Lenses 31 (3d ed. 1977). The classic example of a toroid is the shape generated when a circle is rotated about a line that does not intersect the circle, which describes a torus, a figure

resembling a doughnut or tire. A toroidal surface is the shape of a segment of the surface of a toroid. Id.

Although the parties agree that the term “toroidal” has a well-understood definition, neither party suggests that the term “substantially spherical, concave reflective surface . . . having a cylindrical component added thereto,” used in the claims of the ’143 patent, has a precise and well-established meaning in the art. Rather, the evidence before the trial court indicates that the reference to spheres and cylinders is borrowed from thin lens theory, and that a lens characterized as spherical with a cylindrical component is one with an optical function achieved by “stacking” spherical and cylindrical lenses. The evidence shows that the same nomenclature is sometimes used, albeit with some lack of precision, to refer to reflective surfaces having similar optical properties to such stacked lenses, even though reflective surfaces cannot be stacked in the same manner as lenses.

Because the phrase “substantially spherical . . . having a cylindrical component added thereto” has no precise and generally understood meaning in the art as applied to reflective surfaces, we look to the intrinsic evidence, in this case the specification, for guidance as to the meaning of that language as used in the patent. See Teleflex, Inc. v. Ficoso N. Am. Corp., 299 F.3d 1313, 1324-25 (Fed. Cir. 2002) (“The words used in the claim are interpreted in light of the intrinsic evidence of record . . . . The intrinsic evidence may provide context and clarification about the meaning of claim terms. ‘Such intrinsic evidence is the most significant source of the legally operative meaning of disputed claim language.’” (citations omitted)); Genentech, Inc. v. Wellcome Found. Ltd., 29 F.3d 1559, 1563 (Fed. Cir. 1994) (“Since a definition of [the critical claim]

phrase cannot be extracted from the claims themselves, we look to the specification for guidance.”); see also United States v. Adams, 383 U.S. 39, 49 (1966) (“[C]laims are to be construed in the light of the specifications and both are to be read with a view to ascertaining the invention.”).

Although in this case, as in others, “the guidance [in the specification] is not provided in explicit definitional format,” Ideto Access, Inc. v. Echostar Satellite Corp., No. 04-1154, slip op. at 8 (Fed. Cir. Sept. 14, 2004), the specification of the ’143 patent nonetheless demonstrates that the claim language encompasses toroidal surfaces. First, the specification refers to the curved surfaces in the preferred embodiment of the invention as toroidal surfaces (“the toroids of the surfaces 62, 64,” ’143 patent, col. 4, line 16), and in doing so it describes those surfaces by using the same language that is used in claim 1 (“generally spherical reflective surfaces,” each of which “has a cylindrical component superimposed thereupon,” id., col. 4, ll. 7-10). Accordingly, the specification makes it clear that, for purposes of the ’143 patent, a toroidal surface is a substantially spherical reflective surface that has a cylindrical component superimposed thereupon.

Second, even if the specification were less explicit in equating the term “toroid” with a generally spherical surface having a cylindrical component added thereto, the reference to the preferred embodiment as having mirrors with toroidal surfaces would give rise to a very strong inference that the claim should be construed to include such surfaces. As this court has explained before, “a claim interpretation that excludes a preferred embodiment from the scope of the claim ‘is rarely, if ever, correct.’” Globetrotter Software, Inc. v. Elan Computer Group, Inc., 362 F.3d 1367, 1381 (Fed.

Cir. 2004), quoting Vitronics Corp. v. Conceptronic, Inc., 90 F.3d 1576, 1583 (Fed. Cir. 1996); see also Int'l Rectifier Corp. v. IXYS Corp., 361 F.3d 1363, 1371 (Fed. Cir. 2004); Modine Mfg. Co. v. U.S. Int'l Trade Comm'n, 75 F.3d 1545, 1550 (Fed. Cir. 1990).

The district court interpreted the reference in the specification to a “contour that approaches toroidal,” ’143 patent, col. 4, line 12, as indicating that the recited surface could include a surface that approximates a toroidal shape, but could not include the toroidal shape itself. We disagree with that interpretation. From the description of the mirror surfaces of the preferred embodiment as “toroids” four lines later in the specification, we think it clear that the words “approaching toroidal” were not meant to exclude curves designed to be toroidal in shape, but simply to indicate that the surfaces recited in the invention were intended to include all curves that closely approximate toroidal, including a toroidal surface itself. Indeed, as a matter of manufacturing tolerances, it is impossible to make a real-world device with a reflecting surface that is perfectly toroidal, just as it is impossible to make a reflecting surface that is a perfect spheroid or a perfect paraboloid. For that reason, even mirrors that are designed to be toroidal, such as the mirrors in Perkin-Elmer’s device, will necessarily merely “approach” the ideal toroidal shape, although they may come very close. Accordingly, we do not agree with the district court that the reference in the specification to a surface that “approaches toroidal” was meant to exclude a device having a surface that is characterized in the art of optical engineering as “toroidal.”

Finally, the patent describes the effect of adding a cylindrical component to a generally spherical mirror as being “to reduce the effective radius of curvature in one

plane, thus enabling light incident on the reflective surface to better approach the focus in the orthogonal plane,” ’143 patent, col. 4, ll. 60-62, and “to increase coincidence of foci in two orthogonal planes,” id., col. 5, ll. 51-52. A toroidal surface “has two principal radii of curvature corresponding to its two principal curves,” M. Jolie, supra, at 31; see also Jurgen R. Meyer-Arendt, Introduction to Classical & Modern Optics 120 (3d ed. 1989) (“A toric surface has two radii of curvature (different in the two principal meridians)”; Daniel Malacara, Optical Shop Testing 754 (2d ed. 1992). That characteristic makes toroidal surfaces useful in counteracting astigmatism. See Eugene Hecht, Optics 211-12 (3d ed. 1998). Thus, while the claim language in the ’143 patent does not either expressly include a toroidal surface or exclude other similar surfaces, the characteristics and function of the surface described in the specification and the claims are consistent with the characteristics and function of a toroidal surface.

The district court relied on extrinsic evidence that the court interpreted as supporting its claim construction. Extrinsic evidence, however, cannot be used to alter a claim construction dictated by a proper analysis of the intrinsic evidence. See Intel Corp. v. VIA Techs., Inc., 319 F.3d 1357, 1367 (Fed. Cir. 2003) (“When an analysis of intrinsic evidence resolves any ambiguity in a disputed claim term, it is improper to rely on extrinsic evidence to contradict the meaning so ascertained.”); Frank’s Casing Crew & Rental Tools, Inc. v. PMR Techs., Ltd., 292 F.3d 1363, 1374 (Fed. Cir. 2002); Bell & Howell Document Mgmt. Prods. Co. v. Altek Sys., 132 F.3d 701, 706 (Fed. Cir. 1997). In any event, we do not agree with the district court’s analysis of the extrinsic evidence.

Although the evidence showed, and On-Line’s witnesses acknowledged, that the mathematical description of a toroid differs from that of a spherocylinder, On-Line

offered evidence that a person of skill in fabricating optics would understand the expression "sphere with cylindrical correction" or a sphere "having a cylindrical component" to refer not to a mathematical concept but to the type of optical correction obtained by stacking thin lenses, one having a spherically curved surface and another having a cylindrically curved surface. According to On-Line's expert, a person of ordinary skill in the art would understand the term "sphere with cylindrical correction," as a way of describing the curved surfaces used in On-Line and Perkin-Elmer's commercial products, i.e., toroidal surfaces. The evidence in the summary judgment record therefore provides further support for On-Line's contention that the surface of the objective mirrors recited in claim 1 of the '143 patent includes toroidal surfaces, as that term is understood by persons of skill in the pertinent art, as opposed to the manner in which it is used by mathematicians.

To be sure, On-Line's inventors acknowledged that as a mathematical concept a toroidal surface is not the same thing as a spherical surface with a cylindrical component added to it. That is not to say, however, that the inventors regarded toroidal surfaces as falling outside the broader claim language, which referred to "substantially spherical" surfaces "having a cylindrical component added thereto." As On-Line's expert explained, "the sphere/cylinder convention does not specify the exact mathematical surface . . . . A person of ordinary skill in the art would understand the term 'sphere with cylindrical correction' as a terse and natural way to describe the modestly curved surfaces of the objective mirrors in On-Line's or Perkin-Elmer's gas cell [both of which are toroidal]." Moreover, while acknowledging that the mathematical definition of a toroid differs from that of a spheric cylinder, co-inventor Robert Carangelo

testified that the claim language “substantially spherical . . . having a cylindrical component added” includes a toroidal surface. The other co-inventor, David Wright, testified to similar effect, stating that the claim language was intended to cover a range of conic sections, including ellipsoids and toroids, all of which would have the same shape near the axis “to within the order of machining tolerance.” Finally, even the technical article on which Perkin-Elmer relies to demonstrate that there is a mathematical distinction between toroidal and spherocylindrical surfaces points out that the distinction is extremely subtle for most applications and that toroidal surfaces “are sometimes also [referred to] as spherocylindrical surfaces.” Carmen Menchaca & Daniel Malacara, Toroidal and Spherocylindrical Surfaces, 25 Applied Optics 3008 (1986).

Because of the lack of precision in the language used to define the claimed surfaces of the objective mirrors, this case was made more difficult than it needed to be, and the district court was required to invest considerable effort in trying to ascertain the meaning of the critical claim language. While the district court conducted a careful analysis of the claim language in light of the specification and the extrinsic evidence, we are nonetheless persuaded, particularly in light of the specification, that the district court's claim construction was too restrictive and that a surface designed to be toroidal is within the scope of claim 1 of the '143 patent. Accordingly, because the summary judgment of noninfringement was based on an erroneous claim construction, we vacate the judgment of noninfringement and remand the case for further proceedings on the remaining issues pertinent to On-Line's claim of infringement.



Invoking the district court's supplemental jurisdiction, On-Line raised a number of state law claims, including claims that Perkin-Elmer had misappropriated five trade secrets relating to On-Line's gas cell, in violation of the Connecticut Uniform Trade Secrets Act, Conn. Gen. Stat. § 35-50 et seq. ("CUTSA"). The district court concluded that no reasonable jury could find that Perkin-Elmer had misappropriated any of On-Line's trade secrets. On-Line challenges that ruling with respect to two of the trade secrets that it alleges Perkin-Elmer misappropriated: the long-path gas cell and the Norton igniter source.

A. The Long-Path Gas Cell Trade Secret Claim

In the district court, On-Line alleged that Perkin-Elmer misappropriated confidential information relating to the design of On-Line's long-path gas cell. The district court ruled that On-Line failed to prove actionable misappropriation because the information at issue was disclosed in the '143 patent and because On-Line failed to point to any evidence that Perkin-Elmer had improperly used any information relating to the gas cell prior to the issuance of the patent. Based on the summary judgment record, the district court concluded that undisputed evidence showed that Perkin-Elmer did not begin to incorporate the features of On-Line's gas cell into its own product until 1996, after the issuance of the '143 patent. Although On-Line referred to evidence regarding Perkin-Elmer's conduct before the issuance of the '143 patent, the district court held that none of that evidence was probative of misappropriation because the conduct in question all constituted legitimate evaluation of On-Line's product pursuant to the nondisclosure agreement entered into by On-Line and Perkin-Elmer in 1994. As to

On-Line's claim that not all of the secrets relating to its gas cell were disclosed in the '143 patent, the court found that claim to be unsupported by any evidence.

After a patent has issued, the information contained within it is ordinarily regarded as public and not subject to protection as a trade secret. See Restatement (Third) of Unfair Competition § 39 cmt. f (1995) ("Information that is generally known or readily ascertainable through proper means . . . by others to whom it has potential economic value is not protectable as a trade secret. Thus, information that is disclosed in a patent or contained in published materials reasonably accessible to competitors does not qualify for protection [as a trade secret]."); Conmar Prods. Corp. v. Universal Slide Fastener Co., 172 F.2d 150, 155-56 (2d Cir. 1949) (L. Hand). Moreover, the nondisclosure agreement in this case specifically provided that the obligation of confidentiality created by the agreement "will not apply to any information . . . which becomes publicly available other than by breach of this agreement." Consequently, On-Line cannot claim that Perkin-Elmer's activities following the issuance of the '143 patent constituted misappropriation of confidential information unless the activities related to information not disclosed in the patent.

In the district court, On-Line claimed that Perkins-Elmer had misappropriated information relating to the design of the long-path gas cell and had used it to build its own long-path gas cell prior to the issuance of the '143 patent. The district court, however, concluded that the evidence to which On-Line pointed did not create a genuine issue of material fact on that issue, and we agree. As characterized by the district court, the evidence showed that Perkin-Elmer took various steps to evaluate the On-Line technology that it was considering buying, but did not show that Perkin-Elmer

began building its own gas cell before 1996. Although On-Line asserts that the evidence of Perkin-Elmer's course of conduct with respect to On-Line's product shows that it made use of On-Line's gas cell trade secret before the issuance of the '143 patent, On-Line's general characterizations do not satisfy the requirement that it point to specific evidence sufficient to create a disputed issue of material fact. See Celotex Corp. v. Catrett, 477 U.S. 317, 324 (1986) (non-movant in summary judgment proceedings must "designate specific facts showing that there is a genuine issue for trial"); Crown Operations Int'l, Ltd. v. Solutia Inc., 289 F.3d 1367, 1377 (Fed. Cir. 2002) ("non-moving party must affirmatively demonstrate by specific factual allegations that a genuine issue of material fact exists for trial"); S. Bravo Sys., Inc. v. Containment Techs. Corp., 96 F.3d 1372, 1376 (Fed. Cir. 1996) (unsupported assertions do not satisfy requirement of designating specific evidence creating a genuine issue of material fact).

We also reject On-Line's argument that Perkin-Elmer's acts of copying and testing On-Line's gas cell during the period covered by the nondisclosure agreement were not authorized by the agreement and therefore constituted misappropriation. As the district court noted, On-Line did not present any evidence that Perkin-Elmer began to develop its own cell during the period covered by the agreement or otherwise engaged in conduct prohibited by the nondisclosure agreement. Instead, the evidence relating to Perkin-Elmer's conduct with respect to the disclosed technology shows merely that Perkin-Elmer tested and evaluated that technology, which was conduct contemplated by the nondisclosure agreement. Moreover, Robert Hault, a Perkin-Elmer scientist who visited On-Line's facility following the execution of the nondisclosure agreement, submitted an affidavit in which he averred that he had learned nothing

useful about On-Line's gas cell that was not already evident from On-Line's nonconfidential marketing brochure. On-Line did not offer evidence to contradict Dr. Hoult's representation. Because On-Line failed to demonstrate a disputed issue of material fact with respect to the long-path gas cell trade secret claim, we affirm the district court's grant of summary judgment on that issue.

#### B. The Norton Igniter Source Trade Secret Claim

On-Line's second trade secret claim is that Perkin-Elmer misappropriated the infrared light source and assembly used in the On-Line spectrometer. On-Line uses a device known as the Norton 301-T igniter to produce the infrared light beam that is directed into its testing chamber. In the district court, On-Line argued that Perkin-Elmer learned of the Norton 301-T igniter during its visits to On-Line's facility and used that information to produce its own gas cell, which uses the same igniter as a light source. The district court concluded that the use of the Norton 301-T igniter as the light source was not a trade secret because that use was publicly disclosed in a third party's patent, U.S. Patent No. 5,291,022 ("the '022 patent"), which issued in March of 1994.

On appeal, On-Line argues that although the use of the Norton 301-T igniter as a high-intensity infrared radiation source was known, its use for that purpose in connection with a long-path gas cell was not. It was not the Norton 301-T igniter itself that was the protected trade secret, On-Line argues, but rather the specific purpose to which it was put in On-Line's product. In support of that argument, On-Line points to a report by On-Line's expert, Dr. Warren Vidrine, which described the difference between the use of the Norton 301-T igniter in the '022 patent and its use in the On-Line and Perkin-Elmer devices. Specifically, On-Line points to Dr. Vidrine's statement that On-

Line and Perkin-Elmer both “use metal mirrors to reflect radiation back to the source element to reduce the amount of heat which would otherwise be wasted. The ’022 patent source design does not include any reflective mirrors.”

Dr. Vidrine’s report does not suggest that the use of the Norton 301-T igniter as an infrared radiation source in a long-path gas cell constituted a trade secret. Instead, his report is directed to the overall design of the source assembly. Moreover, the disclosure in the ’022 patent of the uses to which a source such as the Norton 301-T ceramic igniter source could be put was very broad. The ’022 patent addresses “the field of light sources, particularly those emitting in the infrared wavelengths, and more particularly to infrared sources used in analytical instruments such as infrared spectrometers.” ’022 patent, col. 1, ll. 5-9. It also explicitly refers to the Norton 301-T igniter as a suitable light source. Id., col. 6, ll. 50-53. Moreover, Dr. Hoult stated that Perkin-Elmer had determined independently that others were using Norton igniters and that by the time of his visit to On-Line’s facility Perkin-Elmer’s biggest competitor had been using Norton igniters in infrared spectrometers for approximately two years. In light of the breadth of the disclosure in the ’022 patent, the evidence that Perkin-Elmer had learned of the Norton igniter independently, and in the absence of any contrary evidence from On-Line, we agree with the district court that no reasonable jury could conclude that the use of a Norton 301-T igniter in an infrared spectrometer constituted a protectable trade secret that Perkin-Elmer misappropriated from On-Line.

On-Line also argued before the district court that Perkin-Elmer misappropriated an On-Line trade secret when it incorporated into its source assembly two reflective surfaces similar to those that On-Line had developed to enhance and collimate the

infrared light beam directed into the testing chamber. In support of that argument, On-Line offered Dr. Vidrine's report, which asserted that the igniter source assembly in Perkin-Elmer's devices, including a reflective cavity and a field mirror, was similar to the source assembly in On-Line's system.

The district court held that On-Line's evidence with regard to the source assembly claim did not raise a disputed issue of material fact, and we agree. Although Dr. Vidrine asserted that, in his opinion, Perkin-Elmer "commenced to copy, adapt and prepare to take advantage of" features of the On-Line source assembly, including the retroreflective cavity, he did not cite evidence to support that assertion. Instead, Dr. Vidrine's assertion was based on his comparison of the optical elements in the source assembly of the On-Line and Perkin-Elmer instruments. With respect to the retroreflector, Dr. Vidrine stated that one of Perkin-Elmer's two products used a "very similar retroreflector" having a "similarly shaped reflective cavity," and that the retroreflector in the other Perkin-Elmer product, although "not a simple copy" of On-Line's design, "produced a functionally similar result." Dr. Vidrine inferred copying based on the fact that Perkin-Elmer "rapidly adopted" a reflective cavity design. With respect to the field mirror, Dr. Vidrine did not claim that Perkin-Elmer's designs were identical to On-Line's design, but asserted that Perkin-Elmer's designs, like On-Line's, were "good optical engineering solutions" for matching a small hot area with the desired beam characteristics of the respective instruments.

In support of its summary judgment motion, Perkin-Elmer offered affidavits from Dr. Hoult, in which he asserted that Perkin-Elmer did not make use of anything he learned about On-Line's source assembly as a result of his visit to On-Line's facility. In

particular, he stated that the optics in the source assembly of the Perkin-Elmer system were "what I would describe as text-book," that the combination of mirrors used in Perkin-Elmer's devices had been developed several years before his contact with On-Line and had first been used in Perkin-Elmer infrared spectrometers in 1989, that the arrangement of mirrors in the various source assemblies is in essence the same as the arrangement of mirrors in an automobile headlight, and that he did not learn from his visit to On-Line's facility that On-Line used a retroreflector in its source assembly.

In rebuttal, On-Line relied principally on a contemporaneous report by Dr. Hoult regarding his trip to On-Line's facility. On-Line argued that the Hoult trip report demonstrated that Dr. Hoult saw On-Line's source assembly during his visit. The report described the source as follows:

Norton gas-igniter, silicon carbide hairpin mounted on a cylinder with easy push-fit access from the front top. Source hangs down so that debris falls harmlessly away. Source collimation appeared to be an off-axis parabola machined directly on the end of an aluminum cylinder. No firm details of lifetime for source.

That discussion of the source housing (a cylinder with easy push-fit access from the front top) could be interpreted to refer to the source assembly at issue in this case. A reasonable jury could conclude that the "off-axis parabola machined directly on the end of an aluminum cylinder" describes a retroreflective cavity designed to focus the radiation emitted by the Norton igniter, especially given that its purpose is for "[s]ource collimation."

Even accepting the inference from the trip report that Dr. Hoult viewed On-Line's source assembly, On-Line's evidence is insufficient to avoid summary judgment because On-Line failed to address the assertions in Dr. Hoult's affidavit that the mirror array in the source assembly was "text-book" and that Perkin-Elmer had used a similar combination of mirrors in a like instrument years earlier. Although On-Line argues that the earlier device did not use a ceramic igniter as the energy source, there was no evidence before the district court that the difference in the energy source rendered On-Line's source assembly sufficiently distinct to constitute a protectable trade secret. Moreover, nothing in the Hoult trip report suggests that the structure of the source assembly was unfamiliar to Dr. Hoult; in fact, the abbreviated description of the source assembly in the trip report suggests the contrary. In any event, the mere description of the source assembly in the Hoult trip report is insufficient to overcome the evidence from Dr. Hoult that the design of source assemblies of the sort used by On-Line was already familiar to Perkin-Elmer and that the design of On-Line's source assembly was not a trade secret that Perkin-Elmer misappropriated as a result of the visit to On-Line's facility. As to that issue, On-Line is essentially limited to Dr. Vidrine's conclusory assertion that Perkin-Elmer misappropriated On-Line's design, and such conclusory assertions by expert witnesses are not sufficient to avoid summary judgment. See Schwing GMBH v. Putzmeister Aktiengesellschaft, 305 F.3d 1318, 1326 (Fed. Cir. 2002); Applied Cos. v. United States, 144 F.3d 1470, 1475 (Fed. Cir. 1998); Arthur A. Collins, Inc. v. N. Telecom Ltd., 216 F.3d 1042, 1046-48 (Fed. Cir. 2000). We therefore uphold the district court's grant of summary judgment as to the source assembly.



### III

In addition to the trade secret claims, On-Line raised state law claims of fraud, breach of contract, and unfair trade practices. The district court granted summary judgment for Perkin-Elmer as to each of those claims. On-Line appeals as to each.

#### A. The Fraud Claim

The district court rejected On-Line's fraud claim on the ground that it fell within the scope of CUTSA and was therefore preempted under CUTSA's preemption provision, Conn. Gen. Stat. § 35-57(a). On-Line argues that its claim is not preempted because the facts on which its fraud claim is based differ from those that support its misappropriation claim. On-Line contends that its fraud claim is based on the proposed business transaction being negotiated by the parties, rather than the misappropriation of trade secrets. The district court concluded otherwise, and we agree.

Section 35-57(a) of the Connecticut General Statutes states that "[u]nless otherwise agreed by the parties, the provisions of this chapter supersede any conflicting tort, restitutionary, or other law of this state pertaining to civil liability for misappropriation of a trade secret." The preemptive effect of that statute is limited by subsection (b), which states that it does not affect "[c]ontractual or other civil liability or relief that is not based upon misappropriation of a trade secret," among other things. Conn. Gen. Stat. § 35-57(b). On-Line contends that its fraud claims are not based upon the misappropriation of a trade secret and thus they are not preempted under section 35-57.

The district court concluded that On-Line's fraud claim was based on the theory that Perkin-Elmer's allegedly fraudulent actions allowed it to misappropriate On-Line's

trade secrets. In the fraud portion of its complaint, On-Line alleged that Perkin-Elmer had induced it to disclose a variety of trade secrets. On-Line now contends that the district court misunderstood its fraud allegations; in its brief On-Line contends that its fraud claim "is related to the proposed business transaction being negotiated by the parties," and is not related to the misappropriation of trade secrets. On-Line focuses in particular on Perkin-Elmer's termination of the licensing negotiations in November 1994 and Perkin-Elmer's allegedly false statement that the evaluation of On-Line's technology was unsatisfactory.

The problem with that characterization of the fraud claim is that it is unclear how that statement—even if false—misled On-Line to its prejudice, see Paiva v. Vanech Heights Constr. Co., 271 A.2d 69, 71 (Conn. 1970), except perhaps to promote the furtive misappropriation of On-Line's trade secrets by suggesting that Perkin-Elmer was uninterested in the technology when in fact Perkin-Elmer intended to copy it. If that is the purpose suggested by On-Line's argument regarding the November 1994 false statement, it merely demonstrates that the ultimate injury to which the alleged fraud was directed was the misappropriation of On-Line's trade secrets. In its brief, On-Line has not suggested any other injury that On-Line suffered as a result of Perkin-Elmer's allegedly fraudulent conduct. The district court therefore properly held that the fraud claim was preempted under section 35-57.

#### B. The Breach of Contract Claim

The district court granted summary judgment with respect to On-Line's breach of contract claim on the ground that the nondisclosure agreement between On-Line and Perkin-Elmer provided no greater protection than that provided by CUTSA. Because

the court concluded that no reasonable jury could find a CUTSA violation, the court held that there could be no breach of contract, either.

On-Line argues that its breach of contract claim is different from its trade secret misappropriation claim. On-Line, however, does not suggest that if it failed to prove misappropriation of trade secrets it would be nonetheless be entitled to relief on a breach of contract theory for violating the covenant not to disclose trade secrets. Instead, in its brief in this court On-Line focuses on the provision of the nondisclosure agreement that imposed on Perkin-Elmer the obligation to return "all copies" of information that On-Line designated as confidential. Because Perkin-Elmer retained some records containing confidential materials relating to the On-Line spectrometer, On-Line argues that the district court improperly granted summary judgment on the breach of contract claim.

The district court addressed On-Line's argument with regard to Perkin-Elmer's alleged failure to return documents and held that On-Line did not raise the failure to return documents as a basis for liability in the breach of contract claim in its complaint. Because On-Line failed to raise that claim in a timely manner, it was not error for the district court to reject On-Line's effort to raise that aspect of the contract as a basis for liability at the summary judgment stage.

### C. The Unfair Trade Practices Claims

The district court held that On-Line's unfair trade practices claims are preempted by CUTSA. In its complaint, On-Line raised claims against Perkin-Elmer under the Connecticut Uniform Trade Practices Act. Specifically, On-Line alleged that Perkin-Elmer had improperly used trade secrets obtained from On-Line to make its own

products and had represented to a variety of parties that On-Line's trade secrets were its own. The district court concluded that those allegations constituted nothing more than CUTSA violations and that the unfair trade practice claims were therefore preempted by section 37-57(a).

On-Line argues that because Perkin-Elmer gained access to its trade secrets under the guise of offering a license agreement, its claims are not preempted by CUTSA. We cannot agree. All of On-Line's allegations relate to the misappropriation of trade secrets, as is clear from On-Line's complaint, which relies upon Perkin-Elmer's alleged acquisition and use of On-Line's confidential information. As a result, we agree with the trial court that CUTSA preempts On-Line's unfair trade practices claims.

#### IV

On-Line contends that the district court erred when it dismissed Sick, A.G., from the lawsuit based on a lack of personal jurisdiction. In support of its argument, On-Line points to several events: a visit by a Sick, A.G., representative to On-Line's facility in East Hartford, Connecticut; a nondisclosure agreement with On-Line signed by a representative of Sick, A.G.; a report prepared by a representative of Sick, A.G., relating to his visit to the On-Line facility; the receipt by Sick, A.G., of a copy of On-Line's business plan; and a subsequent inquiry by Sick, A.G., to On-Line.

The trial court concluded that the evidence offered in support of On-Line's claim of personal jurisdiction over Sick, A.G., was insufficient to establish personal jurisdiction under Connecticut's long-arm statute, Conn. Gen. Stat. § 33-929. The court found that none of the allegations regarding Sick, A.G., were sufficient to constitute tortious conduct under Conn. Gen. Stat. § 33-929(f), solicitation of business under Conn. Gen.

Stat. § 33-929(f)(2), or a business transaction under Conn. Gen. Stat. § 33-929(e). On-Line has not specifically challenged any of those findings, but instead has made only a general assertion that the district court's ruling is "incorrect and inequitable." Because On-Line has failed to point out any specific errors in the district court's analysis, and because the court's jurisdictional ruling is not otherwise flawed, we uphold the district court's ruling that it lacked personal jurisdiction over Sick, A.G.

\* \* \* \* \*

In summary, we affirm the grant of summary judgment with respect to On-Line's state law claims and with respect to the order dismissing Sick, A.G., on grounds of lack of personal jurisdiction. As to the patent claim, we vacate the grant of summary judgment of noninfringement and remand that issue to the district court for further proceedings.

Each party shall bear its own costs for this appeal.

AFFIRMED IN PART, VACATED IN PART, and REMANDED.

column available from Amersham Biosciences. Either approach can be used to separate polymer-active agent isomers having the same molecular weight (positional isomers).

## 5 STORAGE CONDITIONS OF POLYMER-ACTIVE AGENT CONJUGATES

Following conjugation, and optionally additional separation steps, the conjugate mixture may be concentrated, sterile filtered, and stored at low a temperature, typically from about -20 °C to about -80 °C. Alternatively, the conjugate may be lyophilized, either with or without residual buffer and stored as a lyophilized powder. In some instances, it is preferable to exchange a buffer used for conjugation, such as sodium acetate, for a volatile buffer such as ammonium carbonate or ammonium acetate, that can be readily removed during lyophilization, so that the lyophilized powder is absent residual buffer. Alternatively, a buffer exchange step may be used using a formulation buffer, so that the lyophilized conjugate is in a form suitable for reconstitution into a formulation buffer and ultimately for administration to a mammal.

## ACTIVE AGENTS AND SURFACES

The water-soluble polymers bearing a carboxylic acid or ester thereof presented herein, can be attached, either covalently or non-covalently, to a number of entities including films, chemical separation and purification surfaces, solid supports, metal surfaces such as gold, titanium, tantalum, niobium, aluminum, steel, and their oxides, silicon oxide, macromolecules (e.g., proteins, polypeptides, and so forth), and small molecules. Additionally, the polymers can also be used in biochemical sensors, bioelectronic switches, and gates. The polymers can also be employed as carriers for peptide synthesis, for the preparation of polymer-coated surfaces and polymer grafts, to prepare polymer-ligand conjugates for affinity partitioning, to prepare cross-linked or non-cross-linked hydrogels, and to prepare polymer-cofactor adducts for bioreactors.

A biologically active agent for use in coupling to a polymer as presented herein may be any one or more of the following. Suitable agents can be selected from, for example, hypnotics and sedatives, psychic energizers, tranquilizers,

respiratory drugs, anticonvulsants, muscle relaxants, antiparkinson agents (dopamine antagonists), analgesics, anti-inflammatories, antianxiety drugs (anxiolytics), appetite suppressants, antimigraine agents, muscle contractants, anti-infectives (antibiotics, antivirals, antifungals, vaccines) antiarthritics, antimalarials, 5 antiemetics, antiepileptics, bronchodilators, cytokines, growth factors, anti-cancer agents, antithrombotic agents, antihypertensives, cardiovascular drugs, antiarrhythmics, antioxidants, anti-asthma agents, hormonal agents including contraceptives, sympathomimetics, diuretics, lipid regulating agents, antiandrogenic agents, antiparasitics, anticoagulants, neoplastics, antineoplastics, hypoglycemics, 10 nutritional agents and supplements, growth supplements, antienteritis agents, vaccines, antibodies, diagnostic agents, and contrasting agents.

More particularly, the active agent may fall into one of a number of structural classes, including but not limited to small molecules (preferably insoluble small molecules), peptides, polypeptides, proteins, polysaccharides, steroids, 15 nucleotides, oligonucleotides, polynucleotides, fats, electrolytes, and the like. Preferably, an active agent for coupling to a polymer as described herein possesses a native amino group, or alternatively, is modified to contain at least one reactive amino group suitable for conjugating to a polymer described herein.

Specific examples of active agents suitable for covalent attachment include 20 but are not limited to asparaginase, amdoxovir (DAPD), antide, becaplermin, calcitonins, cyanovirin, denileukin diftitox, erythropoietin (EPO), EPO agonists (e.g., peptides from about 10-40 amino acids in length and comprising a particular core sequence as described in WO 96/40749), dornase alpha, erythropoiesis stimulating protein (NESP), coagulation factors such as Factor V, Factor VII, 25 Factor VIIa, Factor VIII, Factor IX, Factor X, Factor XII, Factor XIII, von Willebrand factor; ceredase, cerezyme, alpha-glucosidase, collagen, cyclosporin, alpha defensins, beta defensins, exedin-4, granulocyte colony stimulating factor (GCSF), thrombopoietin (TPO), alpha-1 proteinase inhibitor, elcatonin, granulocyte macrophage colony stimulating factor (GMCSF), fibrinogen, filgrastim, growth 30 hormones human growth hormone (hGH), growth hormone releasing hormone (GHRH), GRO-beta, GRO-beta antibody, bone morphogenic proteins such as bone morphogenic protein-2, bone morphogenic protein-6, OP-1; acidic fibroblast

growth factor, basic fibroblast growth factor, CD-40 ligand, heparin, human serum albumin, low molecular weight heparin (LMWH), interferons such as interferon alpha, interferon beta, interferon gamma, interferon omega, interferon tau, consensus interferon; interleukins and interleukin receptors such as interleukin-1  
5 receptor, interleukin-2, interleukin-2 fusion proteins, interleukin-1 receptor antagonist, interleukin-3, interleukin-4, interleukin-4 receptor, interleukin-6, interleukin-8, interleukin-12, interleukin-13 receptor, interleukin-17 receptor; lactoferrin and lactoferrin fragments, luteinizing hormone releasing hormone (LHRH), insulin, pro-insulin, insulin analogues (e.g., mono-acylated insulin as  
10 described in U.S. Patent No. 5,922,675), amylin, C-peptide, somatostatin, somatostatin analogs including octreotide, vasopressin, follicle stimulating hormone (FSH), influenza vaccine, insulin-like growth factor (IGF), insulintropin, macrophage colony stimulating factor (M-CSF), plasminogen activators such as alteplase, urokinase, reteplase, streptokinase, pamiteplase, lanoteplase, and  
15 tenecteplase; nerve growth factor (NGF), osteoprotegerin, platelet-derived growth factor, tissue growth factors, transforming growth factor-1, vascular endothelial growth factor, leukemia inhibiting factor, keratinocyte growth factor (KGF), glial growth factor (GGF), T Cell receptors, CD molecules/antigens, tumor necrosis factor (TNF), monocyte chemoattractant protein-1, endothelial growth factors,  
20 parathyroid hormone (PTH), glucagon-like peptide, somatotropin, thymosin alpha 1, rasburicase, thymosin alpha 1 IIB/IIIA inhibitor, thymosin beta 10, thymosin beta 9, thymosin beta 4, alpha-1 antitrypsin, phosphodiesterase (PDE) compounds, VLA-4 (very late antigen-4), VLA-4 inhibitors, bisphosphonates, respiratory syncytial virus antibody, cystic fibrosis transmembrane regulator (CFTR) gene,  
25 deoxyribonuclease (Dnase), bactericidal/permeability increasing protein (BPI), and anti-CMV antibody. Exemplary monoclonal antibodies include etanercept (a dimeric fusion protein consisting of the extracellular ligand-binding portion of the human 75 kD TNF receptor linked to the Fc portion of IgG1), abciximab, afelimomab, basiliximab, daclizumab, infliximab, ibritumomab tiuxetan, mitumomab, muromonab-CD3, iodine 131 tositumomab conjugate, olizumab,  
30 rituximab, trastuzumab (herceptin), and adalimumab.



Additional agents suitable for covalent attachment include, but are not limited to, adefovir, alosetron, amifostine, amiodarone, aminocaproic acid, aminohippurate sodium, aminogluthethimide, aminolevulinic acid, aminosalicic acid, amsacrine, anagrelide, anastrozole, aripiprazole, asparaginase, anthracyclines, 5 bexarotene, bicalutamide, bleomycin, buserelin, busulfan, cabergoline, capecitabine, carboplatin, carmustine, chlorambucin, cilastatin sodium, cisplatin, cladribine, clodronate, cyclophosphamide, cyproterone, cytarabine, camptothecins, 13-cis retinoic acid, all trans retinoic acid; dacarbazine, dactinomycin, daunorubicin, deferoxamine, dexamethasone, diclofenac, diethylstilbestrol, 10 docetaxel, doxorubicin, dutasteride, epirubicin, estramustine, etoposide, exemestane, ezetimibe, fexofenadine, fludarabine, fludrocortisone, fluorouracil, fluoxymesterone, flutamide, fondaparinux, fulvestrant, gamma-hydroxybutyrate, gemcitabine, epinephrine, L-Dopa, hydroxyurea, idarubicin, ifosfamide, imatinib, irinotecan, itraconazole, goserelin, letrozole, leucovorin, levamisole, lisinopril, 15 lovothyroxine sodium, lomustine, mechlorethamine, medroxyprogesterone, megestrol, melphalan, mercaptopurine, metaraminol bitartrate, methotrexate, metoclopramide, mexiletine, mitomycin, mitotane, mitoxantrone, naloxone, nicotine, nilutamide, nitisinone, octreotide, oxaliplatin, pamidronate, pentostatin, pilcamycin, porfimer, prednisone, procarbazine, prochlorperazine, ondansetron, 20 oxaliplatin, raltitrexed, sirolimus, streptozocin, tacrolimus, pimecrolimus, tamoxifen, tegaserod, temozolomide, teniposide, testosterone, tetrahydrocannabinol, thalidomide, thioguanine, thiotepa, topotecan, treprostinil, tretinoin, valdecixib, celecoxib, rofecoxib, valrubicin, vinblastine, vincristine, vindesine, vinorelbine, voriconazole, dolasetron, granisetron; formoterol, 25 fluticasone, leuprolide, midazolam, alprazolam, amphotericin B, podophylotoxins, nucleoside antivirals, aroyl hydrazones, sumatriptan; macrolides such as erythromycin, oleandomycin, troleandomycin, roxithromycin, clarithromycin, davericin, azithromycin, flurithromycin, dirithromycin, josamycin, spiramycin, midecamycin, loratadine, desloratadine, leucomycin, miocamycin, rokitamycin, 30 andazithromycin, and swinolide A; fluoroquinolones such as ciprofloxacin, ofloxacin, levofloxacin, trovafloxacin, alatrofloxacin, moxifloxacin, norfloxacin, enoxacin, grepafloxacin, gatifloxacin, lomefloxacin, sparfloxacin, temafloxacin,

pefloxacin, amifloxacin, fleroxacin, tosufloxacin, prulifloxacin, irloxacin, pazufloxacin, clinafloxacin, and sitafloxacin; aminoglycosides such as gentamicin, netilmicin, paramecin, tobramycin, amikacin, kanamycin, neomycin, and streptomycin, vancomycin, teicoplanin, rampolanin, mideplanin, colistin, 5 daptomycin, gramicidin, colistimethate; polymyxins such as polymixin B, capreomycin, bacitracin, penems; penicillins including penicillinase-sensitive agents like penicillin G, penicillin V; penicillinase-resistant agents like methicillin, oxacillin, cloxacillin, dicloxacillin, floxacillin, nafcillin; gram negative microorganism active agents like ampicillin, amoxicillin, and hetacillin, cillin, and 10 galampicillin; antipseudomonal penicillins like carbenicillin, ticarcillin, azlocillin, mezlocillin, and piperacillin; cephalosporins like cefpodoxime, cefprozil, ceftbuten, ceftizoxime, ceftriaxone, cephalothin, cephapirin, cephalixin, cephradine, cefoxitin, cefamandole, cefazolin, cephaloridine, cefaclor, cefadroxil, cephaloglycin, cefuroxime, ceforanide, cefotaxime, cefatrizine, cephacetrile, 15 cefepime, cefixime, cefonicid, cefoperazone, cefotetan, cefmetazole, ceftazidime, loracarbef, and moxalactam, monobactams like aztreonam; and carbapenems such as imipenem, meropenem, and ertapenem, pentamidine isetionate, albuterol sulfate, lidocaine, metaproterenol sulfate, beclomethasone diprepionate, triamcinolone acetamide, budesonide acetonide, fluticasone, ipratropium bromide, flunisolide, 20 cromolyn sodium, and ergotamine tartrate; taxanes such as paclitaxel; SN-38, and tyrophostines.

Preferred small molecules for coupling to a polymer as described herein are those having at least one naturally occurring amino group. Preferred molecules such as these include aminohippurate sodium, amphotericin B, doxorubicin, 25 aminocaproic acid, aminolevulinic acid, aminosalicyclic acid, metaraminol bitartrate, pamidronate disodium, daunorubicin, levothyroxine sodium, lisinopril, cilastatin sodium, mexiletine, cephalixin, deferoxamine, and amifostine.

Preferred peptides or proteins for coupling to a polymer as described herein include EPO, IFN- $\alpha$ , IFN- $\beta$ , consensus IFN, Factor VIII, Factor IX, GCSF, 30 GMCSF, hGH, insulin, FSH, and PTH.

The above exemplary biologically active agents are meant to encompass, where applicable, analogues, agonists, antagonists, inhibitors, isomers, and

pharmaceutically acceptable salt forms thereof. In reference to peptides and proteins, the invention is intended to encompass synthetic, recombinant, native, glycosylated, and non-glycosylated forms, as well as biologically active fragments thereof.

5

#### PHARMACEUTICAL COMPOSITIONS

The present invention also includes pharmaceutical preparations comprising a conjugate as provided herein in combination with a pharmaceutical excipient. Generally, the conjugate itself will be in a solid form (e.g., a precipitate), which can  
10 be combined with a suitable pharmaceutical excipient that can be in either solid or liquid form.

Exemplary excipients include, without limitation, those selected from the group consisting of carbohydrates, inorganic salts, antimicrobial agents, antioxidants, surfactants, buffers, acids, bases, and combinations thereof.

15

A carbohydrate such as a sugar, a derivatized sugar such as an alditol, aldonic acid, an esterified sugar, and/or a sugar polymer may be present as an excipient. Specific carbohydrate excipients include, for example: monosaccharides, such as fructose, maltose, galactose, glucose, D-mannose, sorbose, and the like; disaccharides, such as lactose, sucrose, trehalose, cellobiose, and the like;  
20 polysaccharides, such as raffinose, melezitose, maltodextrins, dextrans, starches, and the like; and alditols, such as mannitol, xylitol, maltitol, lactitol, xylitol, sorbitol (glucitol), pyranosyl sorbitol, myoinositol, and the like.

The excipient can also include an inorganic salt or buffer such as citric acid, sodium chloride, potassium chloride, sodium sulfate, potassium nitrate, sodium  
25 phosphate monobasic, sodium phosphate dibasic, and combinations thereof.

The preparation may also include an antimicrobial agent for preventing or deterring microbial growth. Nonlimiting examples of antimicrobial agents suitable for the present invention include benzalkonium chloride, benzethonium chloride, benzyl alcohol, cetylpyridinium chloride, chlorobutanol, phenol, phenylethyl  
30 alcohol, phenylmercuric nitrate, thimersol, and combinations thereof.

An antioxidant can be present in the preparation as well. Antioxidants are used to prevent oxidation, thereby preventing the deterioration of the conjugate or

other components of the preparation. Suitable antioxidants for use in the present invention include, for example, ascorbyl palmitate, butylated hydroxyanisole, butylated hydroxytoluene, hypophosphorous acid, monothioglycerol, propyl gallate, sodium bisulfite, sodium formaldehyde sulfoxylate, sodium metabisulfite, and combinations thereof.

A surfactant may be present as an excipient. Exemplary surfactants include: polysorbates, such as "Tween 20" and "Tween 80," and pluronics such as F68 and F88 (both of which are available from BASF, Mount Olive, New Jersey); sorbitan esters; lipids, such as phospholipids such as lecithin and other phosphatidylcholines, phosphatidylethanolamines (although preferably not in liposomal form), fatty acids and fatty esters; steroids, such as cholesterol; and chelating agents, such as EDTA, zinc and other such suitable cations.

Acids or bases may be present as an excipient in the preparation. Nonlimiting examples of acids that can be used include those acids selected from the group consisting of hydrochloric acid, acetic acid, phosphoric acid, citric acid, malic acid, lactic acid, formic acid, trichloroacetic acid, nitric acid, perchloric acid, phosphoric acid, sulfuric acid, fumaric acid, and combinations thereof. Examples of suitable bases include, without limitation, bases selected from the group consisting of sodium hydroxide, sodium acetate, ammonium hydroxide, potassium hydroxide, ammonium acetate, potassium acetate, sodium phosphate, potassium phosphate, sodium citrate, sodium formate, sodium sulfate, potassium sulfate, potassium fumarate, and combinations thereof.

The pharmaceutical preparations encompass all types of formulations and in particular those that are suited for injection, e.g., powders that can be reconstituted as well as suspensions and solutions. The amount of the conjugate (i.e., the conjugate formed between the active agent and the polymer described herein) in the composition will vary depending on a number of factors, but will optimally be a therapeutically effective dose when the composition is stored in a unit dose container (e.g., a vial). In addition, the pharmaceutical preparation can be housed in a syringe. A therapeutically effective dose can be determined experimentally by repeated administration of increasing amounts of the conjugate in order to determine which amount produces a clinically desired endpoint.

The amount of any individual excipient in the composition will vary depending on the activity of the excipient and particular needs of the composition. Typically, the optimal amount of any individual excipient is determined through routine experimentation, i.e., by preparing compositions containing varying  
5 amounts of the excipient (ranging from low to high), examining the stability and other parameters, and then determining the range at which optimal performance is attained with no significant adverse effects.

Generally, however, the excipient will be present in the composition in an amount of about 1% to about 99% by weight, preferably from about 5%-98% by  
10 weight, more preferably from about 15-95% by weight of the excipient, with concentrations less than 30% by weight most preferred.

These foregoing pharmaceutical excipients along with other excipients are described in "Remington: The Science & Practice of Pharmacy", 19<sup>th</sup> ed., Williams & Williams, (1995), the "Physician's Desk Reference", 52<sup>nd</sup> ed., Medical  
15 Economics, Montvale, NJ (1998), and Kibbe, A.H., Handbook of Pharmaceutical Excipients, 3<sup>rd</sup> Edition, American Pharmaceutical Association, Washington, D.C., 2000.

The pharmaceutical preparations of the present invention are typically, although not necessarily, administered via injection and are therefore generally  
20 liquid solutions or suspensions immediately prior to administration. The pharmaceutical preparation can also take other forms such as syrups, creams, ointments, tablets, powders, and the like. Other modes of administration are also included, such as pulmonary, rectal, transdermal, transmucosal, oral, intrathecal, subcutaneous, intra-arterial, and so forth.

25 As previously described, the conjugates can be administered injected parenterally by intravenous injection, or less preferably by intramuscular or by subcutaneous injection. Suitable formulation types for parenteral administration include ready-for-injection solutions, dry powders for combination with a solvent prior to use, suspensions ready for injection, dry insoluble compositions for  
30 combination with a vehicle prior to use, and emulsions and liquid concentrates for dilution prior to administration, among others.

## METHODS OF ADMINISTERING

The invention also provides a method for administering a conjugate as provided herein to a patient suffering from a condition that is responsive to treatment with conjugate. The method comprises administering, generally via injection, a therapeutically effective amount of the conjugate (preferably provided as part of a pharmaceutical preparation). The method of administering may be used to treat any condition that can be remedied or prevented by administration of the particular conjugate. Those of ordinary skill in the art appreciate which conditions a specific conjugate can effectively treat. The actual dose to be administered will vary depend upon the age, weight, and general condition of the subject as well as the severity of the condition being treated, the judgment of the health care professional, and conjugate being administered. Therapeutically effective amounts are known to those skilled in the art and/or are described in the pertinent reference texts and literature. Generally, a therapeutically effective amount will range from about 0.001 mg to 100 mg, preferably in doses from 0.01 mg/day to 75 mg/day, and more preferably in doses from 0.10 mg/day to 50 mg/day.

The unit dosage of any given conjugate (again, preferably provided as part of a pharmaceutical preparation) can be administered in a variety of dosing schedules depending on the judgment of the clinician, needs of the patient, and so forth. The specific dosing schedule will be known by those of ordinary skill in the art or can be determined experimentally using routine methods. Exemplary dosing schedules include, without limitation, administration five times a day, four times a day, three times a day, twice daily, once daily, three times weekly, twice weekly, once weekly, twice monthly, once monthly, and any combination thereof. Once the clinical endpoint has been achieved, dosing of the composition is halted.

One advantage of administering the conjugates of the present invention is that individual water-soluble polymer portions can be cleaved off. Such a result is advantageous when clearance from the body is potentially a problem because of the polymer size. Optimally, cleavage of each water-soluble polymer portion is facilitated through the use of physiologically cleavable and/or enzymatically degradable linkages such as urethane, amide, carbonate or ester-containing linkages. In this way, clearance of the conjugate (via cleavage of individual

water-soluble polymer portions) can be modulated by selecting the polymer molecular size and the type functional group that would provide the desired clearance properties. One of ordinary skill in the art can determine the proper molecular size of the polymer as well as the cleavable functional group. For example, one of ordinary skill in the art, using routine experimentation, can determine a proper molecular size and cleavable functional group by first preparing a variety of polymer derivatives with different polymer weights and cleavable functional groups, and then obtaining the clearance profile (e.g., through periodic blood or urine sampling) by administering the polymer derivative to a patient and taking periodic blood and/or urine sampling. Once a series of clearance profiles have been obtained for each tested conjugate, a suitable conjugate can be identified.

It is to be understood that while the invention has been described in conjunction with the preferred specific embodiments thereof, that the foregoing description as well as the experimental that follow are intended to illustrate and not limit the scope of the invention. Other aspects, advantages and modifications within the scope of the invention will be apparent to those skilled in the art to which the invention pertains.

## Experimental

### EXAMPLES

The practice of the invention will employ, unless otherwise indicated, conventional techniques of organic synthesis and the like, which are understood by one of ordinary skill in the art and are explained in the literature. In the following examples, efforts have been made to ensure accuracy with respect to numbers used (e.g., amounts, temperatures, and so forth), but some experimental error and deviation should be accounted for. Unless otherwise indicated, temperature is in degrees Celsius and pressure is at or near atmospheric pressure at sea level. All reagents were obtained commercially unless otherwise indicated. All generated NMR was obtained from a 300 or 400 MHz NMR spectrometer manufactured by Bruker (Billerica, MA). Reference to an "OBO ortho ester" corresponds to esters comprising the 4-methyl-2,6,7-trioxabicyclo[2.2.2]octanyl.

## Example 1

Formation of 4-Bromobutyrate ester of 3-methyl-3-hydroxymethyloxetane(MW = 251.12)

5           3-Methyl-3-hydroxymethyloxetane (10.2g, 0.1 mole) (Sigma-Aldrich Corporation, St. Louis, MO) was dissolved in anhydrous dichloromethane (200 ml). Pyridine (9.8 ml, 0.12 moles) was then added to the solution. Thereafter, the solution was cooled to 0 °C and 4-bromobutyryl chloride (18.5g, 0.1 mole) (Sigma Aldrich Corporation, St. Louis, MO) dissolved in anhydrous  
10   dichloromethane (50 ml) was added dropwise over 20 minutes. The mixture was stirred overnight under argon atmosphere. Next, the reaction mixture was washed with water and dried with anhydrous magnesium sulfate. The solvent was then distilled off under reduced pressure. Yield 23.6g. NMR (d<sub>6</sub>-DMSO): 1.26 ppm (s, 3H), 2.07 ppm (m, 2H), 2.51 ppm (t, 2H), 3.56 ppm (t, 2H), 4.14 ppm (s, 2H),  
15   4.24 ppm (d, 2H), 4.38 ppm (d, 2H).

## Example 2

Formation of 1-(3-Bromopropyl)-4-methyl-2,6,7-trioxabicyclo[2,2,2]octane(MW= 251.12)

20           The product of Example 1 (crude 4-bromobutyrate ester of 3-methyl-3-hydroxymethyloxetane, 20.1g, 0.08 moles) was dissolved in anhydrous dichloromethane (100 ml), the solution was cooled to 0 °C and boron trifluoride diethyl etherate (2.5 ml, 0.022 moles) was added. The mixture was then stirred for four hours at 0 °C. Triethylamine (12 ml) was added, the mixture was stirred for 15  
25   minutes, and the solvent was distilled off under reduced pressure. The crude product was dissolved in ethyl ether (180 ml) and the solution was then filtered to remove the solid impurities. Next, ether was distilled off and the product was distilled under reduced pressure (kugelrohr, 110-115 °C, 0.05 mm Hg). Yield 15.0g. NMR (d<sub>6</sub>-DMSO): 0.74 ppm (s, 3H), 1.68 ppm (m, 2H), 1.88 ppm (m, 2H), 3.52  
30   ppm (t, 2H), 3.81 ppm(s, 6H).

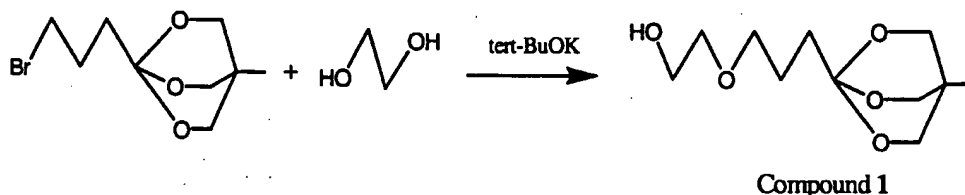


## Example 3

Synthesis of a PEG-Butanoic Acid Precursor Useful in a Polymerization Reaction

A mixture of anhydrous ethylene glycol (120 g, 1.93 moles), 1.0M solution  
5 of potassium tert-butoxide in tert-butanol (70 ml, 0.070 moles), and the product of  
Example 2 [1-(3-bromopropyl)-4-methyl-2,6,7-trioxabicyclo[2,2,2]octane (15 g,  
0.060 moles)] was stirred overnight at 70 °C under an argon atmosphere. After  
cooling to room temperature, the reaction mixture was added to 600 ml of distilled  
water. The product was three-times extracted with dichloromethane (150 ml,  
10 125 ml, and 125 ml). The combined extracts were dried with anhydrous magnesium  
sulfate and the solvent was distilled off under reduced pressure. The product  
(Compound 1) was then subjected to vacuum distillation (kugelrohr,  
t = 120-130 °C, 0.05 mm Hg). Yield 6.2 g. NMR (d<sub>6</sub>-DMSO): 0.74 ppm (s, 3H),  
1.59 ppm (m, 4H), 3.34 ppm (m, 4H), 3.45 ppm (t, 2H), 3.80 ppm (s, 6H), 4.54 ppm  
15 (t, 1H).

Schematically, the reaction can be represented as follows:



20

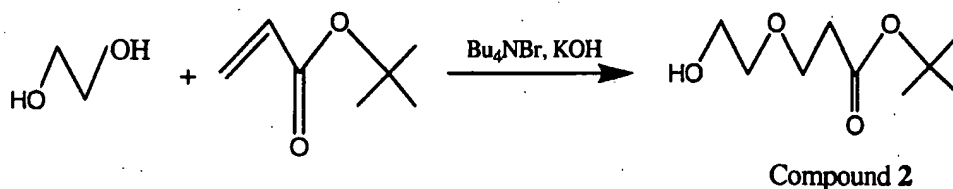
## Example 4

Synthesis of a PEG-Propanoic Acid Precursor Useful in a Polymerization Reaction

Tert-butyl acrylate (130 g, 1.01 mole) was added dropwise over 3 hours to a  
mixture of anhydrous ethylene glycol (62 g, 1.0 mole), tetrabutylammonium  
bromide (9.6 g) and KOH (powder, 2.2 g), and stirred overnight at room  
25 temperature under an argon atmosphere. The volatile products were distilled off  
under reduced pressure (rotovaporator, 60 °C) and the mixture was dissolved in

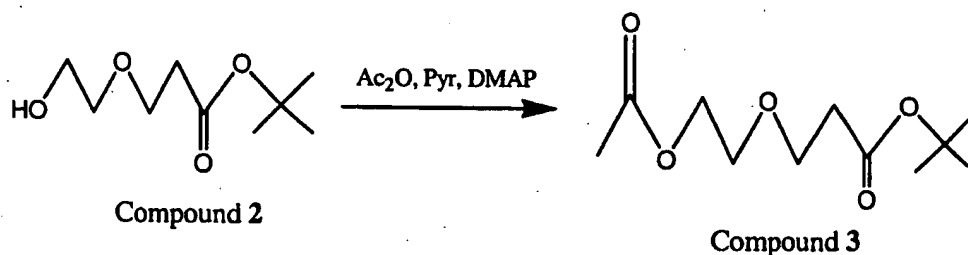
- 250 ml dichloromethane. The solution was washed with 250 ml of distilled water, dried with anhydrous magnesium sulfate, and the solvent was distilled off under reduced pressure. The product (Compound 2) was then subjected to vacuum distillation (kugelrohr,  $t = 95-100\text{ }^{\circ}\text{C}$ , 0.05 mm Hg). Yield 36.6 g. NMR ( $d_6$ -DMSO): 1.40 ppm (s, 9H), 2.42 ppm (t, 2H), 3.39 ppm (m, 2H), 3.46 ppm (m, 2H), 3.59 ppm (s, 2H), 4.55 ppm (t, 1H).

Schematically, the reaction can be represented as follows:



- A mixture of Compound 2 (36.6 g, 0.19 moles), pyridine (52 ml, 0.64 moles), acetic anhydride (52 ml, 0.55 moles) and dimethylaminopyridine (DMAP, 1.0 g) was stirred overnight at room temperature. The volatile products were then distilled off under reduced pressure (rotovaporator,  $t = 65\text{ }^{\circ}\text{C}$ ) and the product (Compound 3) was subjected to vacuum distillation (kugelrohr,  $100-110\text{ }^{\circ}\text{C}$ , 0.05 mm Hg). Yield 40.9 g. NMR ( $d_6$ -DMSO): 1.40 ppm (s, 9H), 2.02 ppm (s, 3H), 2.42 ppm (t, 2H), 3.58 ppm (bm, 4H), 4.08 ppm (m, 2H).

Schematically, the reaction can be represented as follows:

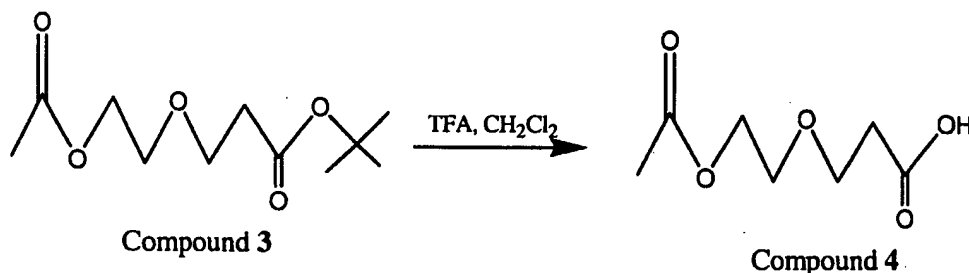


- To compound 3 (30.0 g, 0.19 moles), trifluoroacetic acid (40 ml) was added and the solution was stirred for 1 hour at room temperature. The volatile products were then distilled off under reduced pressure (rotovaporator,  $t = 60\text{ }^{\circ}\text{C}$ ) and the

product was dissolved in 400 ml dichloromethane. The solution was washed twice with 5% NaCl solution and dried with anhydrous magnesium sulfate and the solvent was distilled off under reduced pressure to provide Compound 4. Yield 19.1 g.

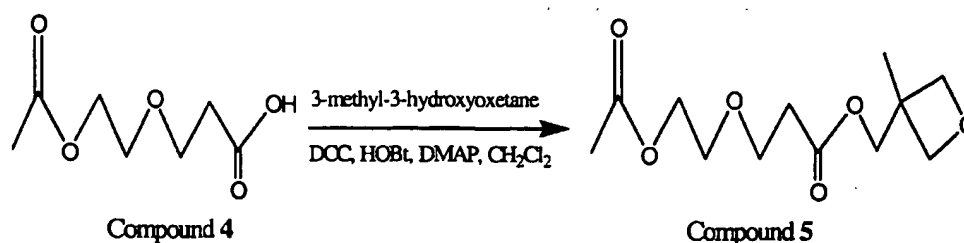
NMR ( $d_6$ -DMSO): 2.01 ppm (s, 3H), 2.44 ppm (t, 2H), 3.57 ppm (m, 2H),  
3.61 ppm (t, 2H) 4.09 ppm (m, 2H).

Schematically, the reaction can be represented as follows:



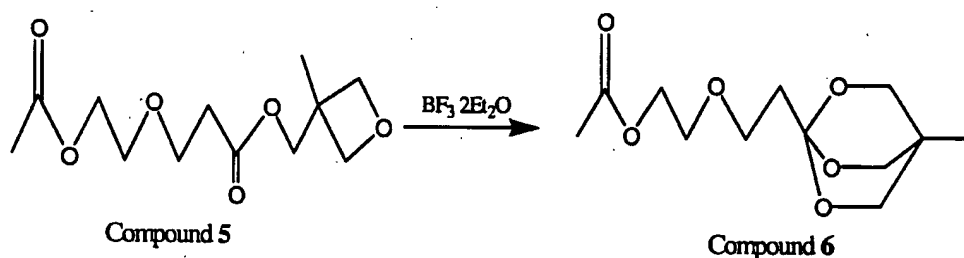
To a solution of compound 4 (19.1 g, 0.108 moles), 3-methyl-3-hydroxyoxetane (17.6 g, 0.172 moles), 1-hydroxybenzotriazole (HOBt, 1.6 g), and DMAP (3.6 g) in anhydrous dichloromethane (500 ml), along with 1,3 dicyclohexylcarbodiimide (DCC, 1.0M solution in dichloromethane, 114 ml, 0.114 moles) was added at 0 °C, and the mixture was stirred overnight at room temperature. The mixture was then filtered to remove precipitated 1,3 dicyclohexylurea and the solution was washed with 250 ml of 5%  $H_3PO_4$ . Next, the dichloromethane was distilled off under reduced pressure (rotovaporator) and the product (Compound 5) was subjected to vacuum distillation (kugelrohr, 125-135 °C, 0.05 mm Hg). Yield 18.5 g. NMR ( $d_6$ -DMSO): 1.26 ppm (s, 3H), 2.00 ppm (s, 3H), 2.59 ppm (t, 2H), 3.57 ppm (m, 2H), 3.66 ppm (t, 2H), 4.08 ppm (m, 2H), 4.14 ppm (s, 2H), 4.23 ppm (d, 2H), 4.38 ppm (d, 2H).

Schematically, the reaction can be represented as follows:



Compound 5 (15.0 g, 0.08 moles) was then dissolved in anhydrous dichloromethane (75 ml), the solution was cooled to 0 °C and boron trifluoride diethyl etherate (1.65 ml) was added. The mixture was then stirred for 3 hours at 0 °C. Triethylamine (7.5 ml) was added, the mixture was stirred for 10 minutes, and the solvent was distilled off under reduced pressure. The crude product (Compound 6) was dissolved in ethyl ether (150 ml) and the solution was filtered to remove the solid impurities. The ether was then distilled off. Yield 12.9 g. NMR ( $d_6$ -DMSO): 0.74 ppm (s, 3H), 1.83 ppm (t, 2H), 2.00 ppm (s, 3H), 3.46 ppm (t, 2H), 3.52 ppm (m, 2H), 3.80 ppm (s, 2H), 3.52 ppm (t, 6H), 4.07 ppm (m, 2H).

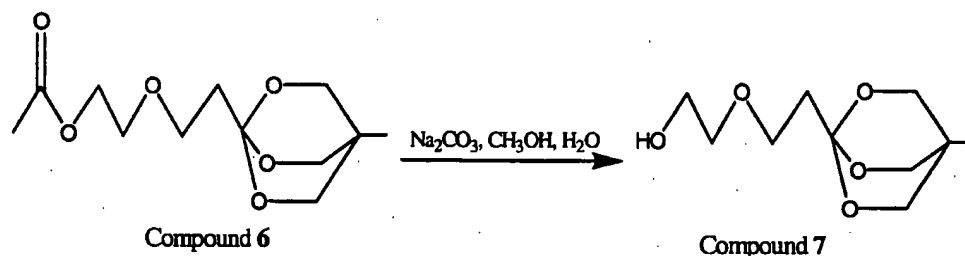
Schematically, the reaction can be represented as follows:



A mixture of compound 6 (12 g), ethyl alcohol (80 ml), and 50% aqueous solution of potassium hydroxide (8 g) was stirred for 40 minutes at room temperature. The solvent was then distilled off under reduced pressure (rotovaporator). The crude product was dissolved in 400 ml dichloromethane and the solution was washed with 5% aqueous solution of sodium chloride. Next, the solution was dried with anhydrous  $MgSO_4$  and the solvent was distilled off under reduced pressure (rotovaporator) giving 8.0 g of colorless liquid product

(Compound 7). NMR ( $d_6$ -DMSO): 0.74 ppm (s, 3H), 1.83 ppm (t, 2H), 3.35 ppm (m, 2H), 3.46 ppm (m, 4H), 3.80 ppm (s, 6H), 3.52 ppm (t, 6H), 4.54 ppm (t, 1H).

Schematically, the reaction can be represented as follows:



5

### Example 5

#### Formation of PEG<sub>(3,500 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -butanoic Acid, OBO Ortho Ester

##### Using Compound 1 as the Initiator for Polymerization

Compound 1 (0.564 g, 0.00243 moles), tetrahydrofuran (THF, 200 ml), and potassium naphthalene, 0.3 mol/l-tetrahydrofuran solution (10 ml, 0.00300 moles) were added to a glass reactor and stirred for 3 minutes in an argon atmosphere. Ethylene oxide (8.8 g, 0.20 moles) was added to this solution and the reaction mixture was stirred for 44 hours at room temperature. Next, the mixture was purged with argon and 0.1M phosphate buffer (pH = 8, 100 ml) was added. The THF layer was separated and discarded. Naphthalene was removed from the solution by ethyl ether extraction. The product was then extracted with dichloromethane (3 x 50 ml). The extract was dried with anhydrous sodium sulfate and the solvent was distilled off under reduced pressure. Yield 7.2 g. NMR ( $d_6$ -DMSO): 0.73 ppm (s, -CH<sub>3</sub> of OBO, 3H), 1.57 ppm (m, -CH<sub>2</sub>-CH<sub>2</sub>-CO-, 4H), 3.51 ppm (s, PEG backbone), 3.80 ppm (s, CH<sub>2</sub> of OBO, 6H), 4.58 ppm (t, OH, 1H).

## Example 6

Formation of PEG<sub>(3,500 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -butanoic Acid

The product of Example 5 (i.e., PEG<sub>(3,500 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -butanoic acid, OBO ortho ester, 7.0 g) was dissolved in distilled water (100 ml). The pH of the solution was adjusted to 2 with 5% phosphoric acid and the solution was stirred for 15 minutes at room temperature. Next, the pH was readjusted to 12 by adding 1M sodium hydroxide and the solution was stirred for two hours while maintaining a pH equal to 12 by periodic addition of 1M sodium hydroxide. The pH was then adjusted to 3 with 5% phosphoric acid, after which the product was extracted with dichloromethane. The extract was dried with anhydrous magnesium sulfate and added to ethyl ether. The precipitated product was filtered off and dried under reduced pressure. Yield 6.6 g. NMR (d<sub>6</sub>-DMSO): 1.72 ppm (q, CH<sub>2</sub>-CH<sub>2</sub>-COO-, 2H) 2.24 ppm (t, -CH<sub>2</sub>-COO-, 2H), 3.51 ppm (s, PEG backbone), 4.58 ppm (t, -OH, 1H).

## Example 7

Formation of mPEG<sub>(3,500 Da)</sub>-butanoic Acid, OBO Ortho Ester

A mixture of the product of Example 5 (i.e., PEG<sub>(3,500 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -butanoic acid, OBO ortho ester, 7.0 g, 0.002 moles), toluene (100 ml), 1.0M solution of potassium tert-butoxide in tert-butanol (10 ml, 0.01 moles), and methyl p-toluenesulfonate (1.49 g, 0.008 moles) was stirred overnight at 45 °C. The solvents were distilled off under reduced pressure (rotoevaporator). The crude product was dissolved in dichloromethane and added to cold ethyl ether. The precipitated product was filtered off and dried under reduced pressure. Yield 6.2 g. NMR (d<sub>6</sub>-DMSO): 0.73 ppm (s, -CH<sub>3</sub> of OBO, 3H), 1.57 ppm (m, -CH<sub>2</sub>-CH<sub>2</sub>-CO-, 4H), 3.24 ppm (s, -OCH<sub>3</sub>, 3H), 3.51 ppm (s, PEG backbone), 3.80 ppm (s, CH<sub>2</sub> of OBO, 6H).

## Example 8

Formation of mPEG<sub>(3,500 Da)</sub>-butanoic Acid

The product of Example 7 (mPEG<sub>(3,500 Da)</sub>-butanoic acid, OBO ortho ester, 6.0 g) was dissolved in distilled water (60 ml). The pH of the solution was adjusted to 2 with 5% phosphoric acid and the solution was stirred for 15 minutes at room temperature. Next, the pH was readjusted to 12 with 1M sodium hydroxide and the solution was stirred for 2 hours. The pH of 12 was maintained by periodic addition of 1M sodium hydroxide. After two hours of stirring and maintaining a pH of 12, the pH was adjusted to 3 with 5% phosphoric acid and the product was extracted with dichloromethane. The extract was then dried with anhydrous magnesium sulfate and added to ethyl ether. The precipitated product was filtered off and dried under reduced pressure. Yield 5.6 g. NMR (d<sub>6</sub>-DMSO): 1.72 ppm (q, CH<sub>2</sub>-CH<sub>2</sub>-COO-, 2H) 2.24 ppm (t, -CH<sub>2</sub>-COO-, 2H), 3.24 ppm (s, CH<sub>3</sub>O-, 3H), 3.51 ppm (s, PEG backbone).

## Example 9

Formation of PEG<sub>(5,000 Da)</sub>-α-hydroxy-ω-propanoic Acid, OBO Ortho EsterUsing Compound 7 as the Initiator for Polymerization

Compound 7 (0.53 g, 0.00243 moles), tetrahydrofuran (THF, 200 ml), and potassium naphthalene 0.3 mol/l-tetrahydrofuran solution (10 ml, 0.00300 moles) were added to a glass reactor and stirred for three minutes in an argon atmosphere. Ethylene oxide (12.2 g, 0.277 moles) was added to this solution and the reaction mixture was stirred for 44 hours at room temperature. Next, the mixture was purged with argon and 0.1M phosphate buffer (pH = 8, 100 ml) was added. The THF layer was separated and then discarded. Naphthalene was removed from the solution by ethyl ether extraction. Thereafter, the product was extracted with dichloromethane (3 x 50 ml). The extract was dried with anhydrous sodium sulfate and the solvent was distilled off under reduced pressure. Yield 11.7 g. NMR (d<sub>6</sub>-DMSO): 0.73 ppm (s, -CH<sub>3</sub>, 3H), 1.82 ppm (t, -CH<sub>2</sub>-CO-, 2H), 3.51 ppm (s, PEG backbone), 3.80 ppm (s, CH<sub>2</sub> of OBO, 6H), 4.57 ppm (t, -OH, 1H).

## Example 10

Formation of PEG<sub>(5,000 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -propanoic Acid

The product of Example 9 (PEG<sub>(5,000 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -propanoic acid, OBO  
5 ortho ester, 5.0 g) was dissolved in distilled water (75 ml). The pH of the solution  
was adjusted to 2 with 5% phosphoric acid and the solution was stirred 15 minutes  
at room temperature. Next, the pH was readjusted to 12 with 1M sodium hydroxide  
and the solution was stirred for two hours. The pH of the solution was maintained  
at a pH equaling 12 by periodic addition of 1M sodium hydroxide. After two hours  
10 of stirring and maintaining the pH at 12, the pH of the solution was adjusted to 3  
with 5% phosphoric acid and the product was thereafter extracted with  
dichloromethane. The extract was then dried with anhydrous magnesium sulfate  
and added to ethyl ether. The precipitated product was filtered off and dried under  
reduced pressure. Yield 4.4 g. NMR (d<sub>6</sub>-DMSO): 2.43 ppm (t, -CH<sub>2</sub>-COO-, 2H),  
15 3.51 ppm (s, PEG backbone), 4.58 ppm (t, -OH, 1H).

## Example 11

Formation of mPEG<sub>(5,000 Da)</sub>-propanoic Acid, OBO Ortho Ester

A mixture of the product of Example 9 (PEG<sub>(5,000 Da)</sub>- $\alpha$ -hydroxy- $\omega$ -  
20 propanoic acid, OBO ortho ester, 4.0 g, 0.0008 moles), toluene (50 ml), 1.0M  
solution of potassium tert-butoxide in tert-butanol (8 ml, 0.008 moles), and methyl  
*p*-toluenesulfonate (1.49 g, 0.008 moles) was stirred overnight at 50 °C. Next, the  
solvents were distilled off under reduced pressure (rotovaporator). The crude  
product was then dissolved in dichloromethane and added to cold ethyl ether. The  
25 precipitated product was filtered off and dried under reduced pressure. Yield 3.6 g.  
NMR (d<sub>6</sub>-DMSO): 0.73 ppm (s, -CH<sub>3</sub>, 3H), 1.82 ppm (t, -CH<sub>2</sub>-CO-, 2H), 3.24 ppm  
(s, CH<sub>3</sub>O-, 3H), 3.51 ppm (s, PEG backbone), 3.80 ppm (s, CH<sub>2</sub> of OBO, 6H).



## Example 12

Formation of mPEG<sub>(5,000 Da)</sub>-propanoic Acid

The product of Example 11 (mPEG<sub>(5,000 Da)</sub>-propanoic acid, OBO ortho ester, 6.0 g) was dissolved in distilled water (60 ml). The pH of the solution was  
5 the adjusted to 2 with 5% phosphoric acid and the solution was stirred for 15 minutes at room temperature. Next, the pH was readjusted to 12 with 1M sodium hydroxide and the solution was stirred for two hours. A pH of 12 was maintained by periodic addition of 1M sodium hydroxide. After two hours of stirring and maintaining a pH of 12, the pH of the solution was then adjusted to 3 with 5%  
10 phosphoric acid and the product was then extracted with dichloromethane. The extract was then dried with anhydrous magnesium sulfate and added to ethyl ether. The precipitated product was filtered off and dried under reduced pressure. Yield 5.6 g. NMR (d<sub>6</sub>-DMSO): 2.43 ppm (t, -CH<sub>2</sub>-COO-, 2H), 3.24 ppm (s, CH<sub>3</sub>O-, 3H), 3.51 ppm (s, PEG backbone).

15

## Example 13

Formation of mPEG<sub>(20,000 Da)</sub>-butanoic Acid

A solution of mPEG<sub>(20,000 Da)</sub> (2.0g, 0.0001 moles) (NOF Corporation) in toluene (30 ml) was azeotropically dried by distilling off 15 ml of toluene. 1.0M  
20 solution of potassium tert-butoxide in tert-butanol (0.80 ml, 0.0008000 moles) and the product of Example 2 [1-(3-bromopropyl)-4-methyl-2,6,7-trioxabicyclo[2,2,2]octane, 0.15g, 0.0005973 moles] were added and the mixture was stirred overnight at 70 °C under argon atmosphere. The solvent was distilled off under reduced pressure and the residue was dissolved in distilled water (40 ml).  
25 The pH of the solution was adjusted to 2 with 5% phosphoric acid and the solution was stirred for 15 minutes at room temperature. Next, the pH was readjusted to 12 with 1M sodium hydroxide and the solution was stirred for two hours keeping the pH at 12 by periodic addition of 1M sodium hydroxide. Thereafter, the pH was adjusted to 3 with 5% phosphoric acid and the product was extracted with  
30 dichloromethane. The extract was dried with anhydrous magnesium sulfate and

added to ethyl ether. The precipitated product was filtered off and dried under reduced pressure. Yield 1.6 g. NMR ( $d_6$ -DMSO): 1.72 ppm (q,  $\underline{CH_2}$ -CH<sub>2</sub>-COO-) 2.24 ppm (t, -CH<sub>2</sub>-COO-), 3.24 ppm (s, -OCH<sub>3</sub>), 3.51 ppm (s, PEG backbone). Anion exchange chromatography: mPEG<sub>(20,000)</sub>-butanoic acid 98.6%, m-PEG-20K 1.4%.

#### Example 14

##### Formation of 4-Bromohexanoate Ester of 3-Methyl-3-hydroxymethyloxetane

(MW = 251.12)

3-Methyl-3-hydroxymethyloxetane (20.5g, 0.201 mole) was dissolved in anhydrous dichloromethane (250 ml) and pyridine (20.0 ml, 0.12 moles) was added. The solution was cooled to 0 °C and 4-bromohexanoyl chloride (42.7g, 0.200 mole) dissolved in anhydrous dichloromethane (50 ml) was added dropwise over 20 minutes. Thereafter, the mixture was stirred overnight under argon atmosphere. Next, the reaction mixture was washed with water and dried with anhydrous magnesium sulfate. The solvent was then distilled off under reduced pressure. Yield 56.8g. NMR ( $d_6$ -DMSO): 1.26 ppm (s, 3H), 2.07 ppm (m, 2H), 2.51 ppm (t, 2H), 3.56 ppm (t, 2H), 4.14 ppm (s, 2H), 4.24 ppm (d, 2H), 4.38 ppm (d, 2H).

#### Example 15

##### Formation of 1-(3-Bromopentyl)-4-methyl-2,6,7-trioxabicyclo[2,2,2]octane

The product of Example 14 (crude 4-bromohexanoate ester of 3-methyl-3-hydroxymethyloxetane, 20.1g, 0.08 moles) was dissolved in anhydrous dichloromethane (100 ml), the solution was cooled to 0 °C, and boron trifluoride diethyl etherate (2.5 ml, 0.022 moles) was added. The mixture was then stirred for 4 hours at 0 °C. Triethylamine (12 ml) was added, the mixture was stirred for 15 minutes, and then the solvent was distilled off under reduced pressure. The crude product was then dissolved in ethyl ether (180 ml) and the solution was filtered to remove the solid impurities. Next, ether was distilled off and the product was

distilled under reduced pressure (kugelrohr, 110-115 °C, 0.05 mm Hg). Yield 15.0g.  
NMR ( $d_6$ -DMSO): 0.74 ppm (s, 3H), 1.68 ppm (m, 2H), 1.88 ppm (m, 2H),  
3.52 ppm (t, 2H), 3.81 ppm (s, 6H).

5

## Example 16

Formation of mPEG<sub>(2,000 Da)</sub>-hexanoic Acid

A solution of mPEG<sub>(2,000 Da)</sub> (2.0g, 0.0010 moles) (NOF Corporation) in  
toluene (30 ml) was azeotropically dried by distilling off 15 ml toluene. 1.0M  
solution of potassium tert-butoxide in tert-butanol (0.60 ml, 0.0006000 moles) and  
10 the product of Example 16 [1-(3-bromopentyl)-4-methyl-2,6,7-  
trioxabicyclo[2,2,2]octane, 0.15g, 0.0005973 moles] were added and the mixture  
was stirred overnight at 70 °C under argon atmosphere. The solvent was then  
distilled off under reduced pressure and the residue was dissolved in distilled water  
(40 ml). The pH of the solution was adjusted to 2 with 5% phosphoric acid and the  
15 solution was stirred for 15 minutes at room temperature. Next, the pH was  
readjusted to 12 with 1M sodium hydroxide and the solution was stirred for 2 hours  
while keeping the pH equal to 12 by periodic addition of 1M sodium hydroxide.  
The pH was then adjusted to 3 with 5% phosphoric acid and the product was  
extracted with dichloromethane. The extract was dried with anhydrous magnesium  
20 sulfate and added to ethyl ether. The precipitate was filtered off and dried under  
reduced pressure. Yield 1.6 g. NMR ( $d_6$ -DMSO): 1.72 ppm (q,  $\underline{\text{CH}_2\text{-CH}_2\text{-COO-}}$ )  
2.24 ppm (t,  $\text{-CH}_2\text{-COO-}$ ), 3.24 ppm (s,  $\text{-OCH}_3$ ), 3.51 ppm (s, PEG backbone).

25

## Example 17

Formation of mPEG<sub>(5,000 Da)</sub>-O-CH(CH<sub>2</sub>O(CH<sub>2</sub>)<sub>3</sub>COOH)<sub>2</sub>

A solution of mPEG<sub>(5,000 Da)</sub>-O-CH(CH<sub>2</sub>OH)<sub>2</sub> (2.0g, 0.0004 moles)  
(prepared from mPEG<sub>(5,000 Da)</sub>-mesylate and 1,3-dibenzoyloxy-2-propanol according  
to method described in published U.S. Patent Application US 2001/0011115 ) in  
toluene (30 ml) was azeotropically dried by distilling off 15 ml toluene. 1.0M

solution of potassium tert-butoxide in tert-butanol (2.4 ml, 0.0024 moles) and 1-(3-bromopropyl)-4-methyl-2,6,7-trioxabicyclo[2,2,2]octane, 0.60 g, 0.0024 moles) (prepared as described in Example 2) were added and the mixture was stirred overnight at 70 °C under argon atmosphere. The solvent was distilled off under reduced pressure and the residue was dissolved in distilled water (30 ml). The pH of the solution was adjusted to 2 with 5% phosphoric acid and the solution was stirred for 15 minutes at room temperature. Next, the pH was readjusted to 12 with 1M sodium hydroxide and the solution was stirred for 1.5 hours while maintaining a pH equal to 12 by the periodic addition of 1M sodium hydroxide. Thereafter, the pH was adjusted to 3 with 5% phosphoric acid and the product was extracted with dichloromethane. The extract was then dried with anhydrous magnesium sulfate and added to ethyl ether. The precipitate was filtered off and dried under reduced pressure. Yield 1.6 g. NMR ( $d_6$ -DMSO): 1.72 ppm (q,  $\text{CH}_2\text{-CH}_2\text{-COO-}$ ) 2.24 ppm (t,  $\text{-CH}_2\text{-COO-}$ ), 3.24 ppm (s,  $\text{-OCH}_3$ ), 3.51 ppm (s, PEG backbone).

### Example 18

#### Formation of mPEG<sub>(5,000 Da)</sub>-butanoic Acid

A solution of mPEG<sub>(5,000 Da)</sub> (2.0g, 0.0004 moles) (NOF Corporation) in toluene (20 ml) was azeotropically dried by distilling off solvent to dryness under reduced pressure. The dried material was dissolved in 15 ml of anhydrous toluene. 1.0M solution of potassium tert-butoxide in tert-butanol (1.2 ml, 0.0012 moles) and trimethyl 4-bromoorthobutyrate (Sigma-Aldrich, 0.25g, 0.0011 moles) were added and the mixture was stirred overnight at 70 °C under argon atmosphere. The solvent was distilled off under reduced pressure and the residue was dissolved in distilled water (40 ml). The pH of the solution was adjusted to 2 with 5% phosphoric acid and the solution was stirred for 15 minutes at room temperature. Next the pH was readjusted to 12 with 1M sodium hydroxide and the solution was stirred for 2 hours keeping pH equal 12 by periodic addition of 1M sodium hydroxide. The pH was adjusted to 3 with 5% phosphoric acid and the product was extracted with dichloromethane. The extract was dried with anhydrous magnesium

sulfate and added to ethyl ether. The precipitated product was filtered off and dried under reduced pressure. Yield 1.5 g. NMR ( $d_6$ -DMSO): 1.72 ppm (q,  $\text{CH}_2\text{-CH}_2\text{-COO-}$ ) 2.24 ppm (t,  $\text{-CH}_2\text{-COO-}$ ), 3.24 ppm (s,  $\text{-OCH}_3$ ), 3.51 ppm (s, PEG backbone).

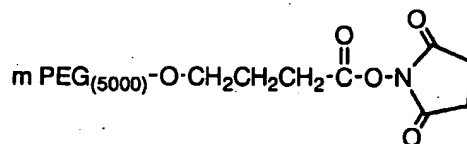
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### Example 19

#### Formation of mPEG-succinimidyl Butanoate

The product of Example 18 (mPEG<sub>(5,000 Da)</sub>-butanoic acid) is dissolved in methylene chloride to form a solution. N-hydroxysuccinimide and  
10 N,N-dicyclohexylcarbodiimide is then dissolved in 2 ml of methylene chloride and is added to the solution, which is then stirred overnight. Next, the mixture is filtered and the filtrate is concentrated under vacuum. The product is precipitated by addition of the filtrate to isopropanol and is then collected by filtration and dried under vacuum. The product is represented as follows:

15



### Example 20

#### Formation of PEGylated Lysozyme

20 Lysozyme serves as a protein model useful for conjugation reactions. Consequently, other active agent proteins can be substituted for lysozyme in this Example.

Lysozyme solution (4ml, 3mg/ml) in 50 ml of pH 6.5 buffer (50 mM sodium phosphate/50 mM NaCl) is added to 20 mg of N-succinimidyl ester of  
25 mPEG<sub>(5,000 Da)</sub>-butanoic acid (the product of Example 19, mPEG-succinimidyl butanoate). The progress of the reaction is monitored by capillary electrophoresis

over a course of six hours to monitor the reaction. After the six hours, capillary electrophoresis shows evidence of PEGylated lysozyme.

#### Example 21

5

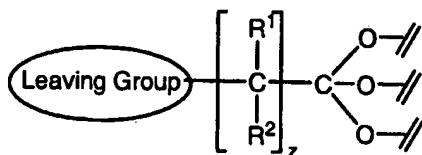
#### Formation of PEGylated Lysozyme

Lysozyme serves as a protein model useful for conjugation reactions. Consequently, other active agent proteins can be substituted for lysozyme in this Example.

10 The product of Example 18 (mPEG<sub>(5,000 Da)</sub>-butanoic acid) is dissolved in 20 ml of methylene chloride at room temperature and a solution is formed. The solution is then treated with 1,3-diisopropylcarbodiimide, 4-dimethylaminopyridine and lysozyme at 0 °C. The reaction solution is then warmed to room temperature after several hours and kept at room temperature for about 16 hours. The reaction mixture is then washed with hydrochloric acid, dried and evaporated to yield the  
15 conjugated product.

What is claimed is:

1. A method for making an ortho ester of a water-soluble polymer comprising the step of reacting a water-soluble polymer segment having at least one alkoxide ion or thiolate ion with an ortho ester comprised of a suitable leaving group.
2. The method of claim 1, wherein the water-soluble polymer segment has at least one alkoxide ion and is prepared via a polymerization reaction.
3. The method of claim 1, wherein the water-soluble polymer segment having at least one alkoxide ion or thiolate ion is prepared by combining a water-soluble polymer segment having at least one hydroxyl or thiol moiety with a suitable base.
4. The method of claim 3, wherein the suitable base is selected from the group consisting of sodium, potassium, sodium hydride, potassium hydride, sodium methoxide, potassium methoxide, sodium tert-butoxide, and potassium tert-butoxide.
5. The method of claim 1, wherein the ortho ester comprised of a suitable leaving group comprises the following structure:



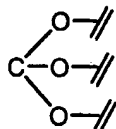
wherein:

$\text{Leaving Group}$  is the suitable leaving group;

(z) is an integer from 1 to 24;

$R^1$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

$R^2$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

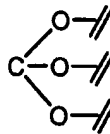


represents a residue of a ortho ester moiety.

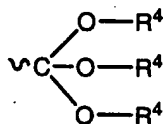
6. The method of claim 5, wherein the suitable leaving group is selected from the group consisting of halogens and sulfonate esters.

7. The method of claim 5, wherein the suitable leaving group is selected from the group consisting of bromo, chloro and iodo.

8. The method of claim 5, wherein the suitable leaving group is selected from the group consisting of methanesulfonate, trifluoromethanesulfonate, trichloromethanesulfonate, 2,2,2-trifluoroethanesulfonate, 2,2,2-trichloroethanesulfonate, and para-toluenesulfonate.

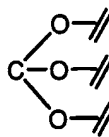


9. The method of claim 5, wherein the following structure: moiety is comprised of the

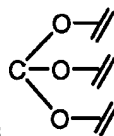




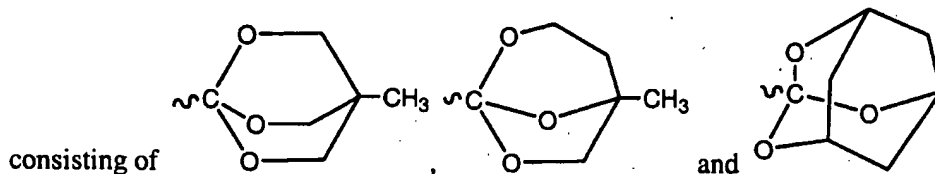
wherein each  $R^4$  is an organic radical independently selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.



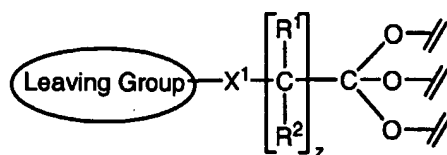
10. The method of claim 5, wherein the moiety is in the form of a cyclic structure.



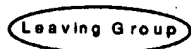
11. The method of claim 10, wherein the moiety is selected from the group



12. The method of claim 5, wherein the ortho ester comprised of a suitable leaving group comprises the following structure:



wherein:



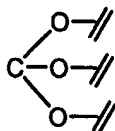
is the suitable leaving group;

$X^1$  is a spacer moiety;

(z) is an integer from 1 to 24;

$R^1$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

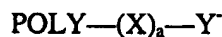
$R^2$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and



represents a residue of a ortho ester moiety.

13. The method of claim 5, wherein the ortho ester moiety comprised of a suitable leaving group is prepared via a polymerization reaction conducted on an initiator molecule having an ortho ester moiety.

14. The method of claim 1, wherein the water-soluble polymer segment having at least one alkoxide ion or thiolate ion is comprised of the following structure:



wherein POLY is a water-soluble polymer segment;

(a) is zero or one;

X, when present, is a spacer moiety; and

Y is O or S.

15. The method of claim 14, wherein the water-soluble polymer segment having at least one alkoxide ion or thiolate ion is comprised of the following structure:



wherein:

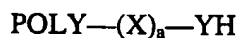
(m) is from 2 to 4000;

Y is O or S; and

R<sup>5</sup> is H or an organic radical selected from the group consisting of alkyl, substituted

alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.

16. The method of claim 3, wherein the water-soluble polymer segment having at least one hydroxyl or thiol group is comprised of the following structure:



wherein:

POLY is a water-soluble polymer segment;

(a) is zero or one;

X, when present, is a spacer moiety; and

Y is O or S.

17. The method of claim 16, wherein the water-soluble polymer segment has one hydroxyl group and is comprised of the following structure:



wherein:

(m) is from 2 to 4000; and

R<sup>5</sup> is H or an organic radical selected from the group consisting of alkyl, substituted

alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.

18. The method of claim 17, wherein the water-soluble polymer segment having one hydroxyl group is comprised of the following structure:



wherein (m) is from 2 to 4000.

19. A method for making a carboxylic acid of a water-soluble polymer comprising the steps of

(a) reacting a water-soluble polymer segment having at least one alkoxide ion or thiolate ion with an ortho ester comprised of a suitable leaving group to form an ortho ester of a water-soluble polymer; and

(b) subjecting the ortho ester of a water-soluble polymer formed in step (a) to at least one hydrolysis step so as to provide the corresponding carboxylic acid of a water-soluble polymer.

20. The method of claim 19, wherein the water-soluble polymer segment having at least one alkoxide ion or thiolate ion is prepared by combining a water-soluble polymer segment having at least one hydroxyl or thiol moiety with a suitable base.

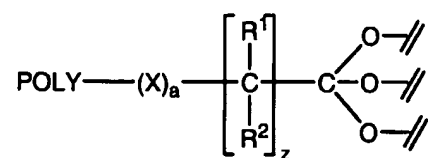
21. The method of claim 19, further comprising the step of recovering the carboxylic acid of the water-soluble polymer.

22. The method of claim 19, further comprising the step of purifying the carboxylic acid of the water-soluble polymer.

23. The method of claim 19, wherein conversion of the ortho ester of the water-soluble polymer into the carboxylic acid of the water-soluble polymer is about 85% or greater.

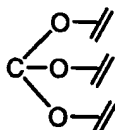
24. The method of claim 19, wherein the at least one hydrolysis step comprises two hydrolysis steps.

25. The method of claim 24, wherein the two hydrolysis steps comprise an initial acid hydrolysis step followed by a base hydrolysis step.
26. A carboxylic acid of a water-soluble polymer prepared by the method of claim 19.
27. An ortho ester of a water-soluble polymer.
28. A polymer comprising the following structure:



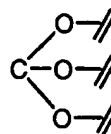
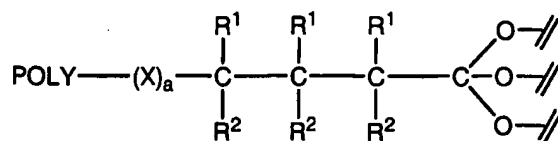
wherein:

- POLY is a water-soluble polymer segment;
- (a) is either zero or one;
- X, when present, is a spacer moiety;
- (z) is an integer from 1 to 24;
- R<sup>1</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;
- R<sup>2</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and



represents a residue of an ortho ester moiety.

29. The polymer of claim 28, wherein (z) equals three and the polymer is comprised of the following structure:

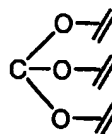
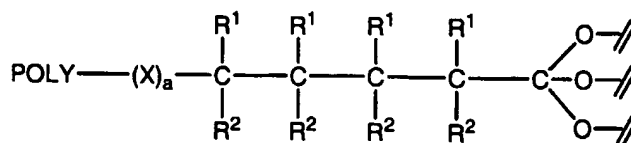


wherein POLY, X, (a), each  $\text{R}^1$ , each  $\text{R}^2$  and  $\text{C}(\text{O}-\text{O}-\text{O})_3$  are as previously defined.

30. The polymer of claim 29, wherein each occurrence of  $\text{R}^1$  and  $\text{R}^2$  is H.

31. The polymer of claim 29, wherein the  $\text{R}^1$  attached to the carbon  $\alpha$  to the carbon in the ortho ester moiety is alkyl, all other  $\text{R}^1$  variables are H, and all  $\text{R}^2$  variables are H.

32. The polymer of claim 28, wherein (z) equals four and the polymer is comprised of the following structure:

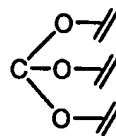
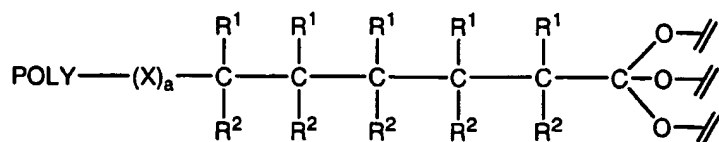


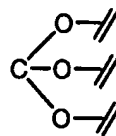
wherein POLY, X, (a), each  $\text{R}^1$ , each  $\text{R}^2$  and  $\text{C}(\text{O}-\text{O}-\text{O})_3$  are as previously defined.

33. The polymer of claim 32, wherein each occurrence of  $\text{R}^1$  and  $\text{R}^2$  is H.

34. The polymer of claim 32, wherein the  $\text{R}^1$  attached to the carbon  $\alpha$  to the carbon in the ortho ester moiety is alkyl, all other  $\text{R}^1$  variables are H, and all  $\text{R}^2$  variables are H.

35. The polymer of claim 28, wherein (z) equals five and the polymer is comprised of the following structure:



wherein POLY, X, (a), each R<sup>1</sup>, each R<sup>2</sup> and  are as previously defined.

36. The polymer of claim 35, wherein each occurrence of R<sup>1</sup> and R<sup>2</sup> is H.

37. The polymer of claim 35, wherein the R<sup>1</sup> attached to the carbon α to the carbon in the ortho ester moiety is alkyl, all other R<sup>1</sup> variables are H, and all R<sup>2</sup> variables are H.

38. The polymer of claim 28, wherein POLY is selected from the group consisting of a poly(alkylene oxide)s, poly(vinyl pyrrolidone), poly(vinyl alcohol), polyoxazoline, poly(acryloylmorpholine), and poly(oxyethylated polyol).

39. The polymer of claim 38, wherein POLY is a poly(alkylene oxide).

40. The polymer of claim 39, wherein the poly(alkylene oxide) is a poly(ethylene glycol).

41. The polymer of claim 40, wherein the poly(ethylene glycol) is terminally capped with an end-capping moiety.

42. The polymer of claim 41, wherein the end-capping moiety is independently selected from the group consisting alkoxy, substituted alkoxy,

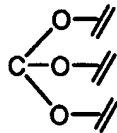
alkenyloxy, substituted alkenyloxy, alkynyloxy, substituted alkynyloxy, aryloxy, substituted aryloxy, and hydroxy.

43. The polymer of claim 42, wherein the end-capping moiety is alkoxy.
44. The polymer of claim 43, wherein the alkoxy is methoxy.
45. The polymer of claim 42, wherein the end-capping moiety is hydroxy.
46. The polymer of claim 40, wherein the poly(ethylene glycol) has a nominal average molecular mass of from about 100 daltons to about 100,000 daltons.
47. The polymer of claim 46, wherein the poly(ethylene glycol) has a nominal average molecular mass of from about 2,000 daltons to about 25,000 daltons.
48. The polymer of claim 47, wherein the poly(ethylene glycol) has a nominal average molecular mass of from about 5,000 daltons to about 20,000 daltons.
49. The polymer of claim 28, wherein (a) equals zero.
50. The polymer of claim 28, wherein (a) equals one.
51. The polymer of claim 50, wherein X is independently selected from the group consisting of -O-, -S-, -C(O)-, -C(O)-NH-, -NH-C(O)-NH-, -O-C(O)-NH-, -C(S)-, -CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -O-CH<sub>2</sub>-, -CH<sub>2</sub>-O-, -O-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-O-, -O-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-O-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-O-, -O-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-O-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-O-, -C(O)-NH-CH<sub>2</sub>-,

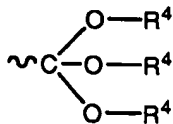


$\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-}$ ,  
 $\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-}$ ,  $\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-}$ ,  $\text{-C(O)-O-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-C(O)-O-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-}$   
 $\text{C(O)-O-CH}_2\text{-}$ ,  $\text{-C(O)-O-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-NH-C(O)-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-NH-C(O)-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-NH-C(O)-CH}_2\text{-}$ ,  $\text{-NH-C(O)-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-NH-C(O)-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-NH-C(O)-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-C(O)-NH-CH}_2\text{-}$ ,  $\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-O-C(O)-NH-CH}_2\text{-}$ ,  $\text{-O-C(O)-NH-CH}_2\text{-CH}_2\text{-}$ ,  $\text{-NH-CH}_2\text{-}$ ,  $\text{-NH-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-NH-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-NH-CH}_2\text{-}$ ,  $\text{-C(O)-CH}_2\text{-}$ ,  $\text{-C(O)-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-C(O)-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-C(O)-CH}_2\text{-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-C(O)-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-C(O)-}$ ,  $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-NH-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-NH-C(O)-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-NH-C(O)-CH}_2\text{-}$ ,  
 $\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-C(O)-NH-CH}_2\text{-CH}_2\text{-NH-C(O)-CH}_2\text{-CH}_2\text{-}$ ,  
 $\text{-O-C(O)-NH-[CH}_2\text{]}_h\text{-(OCH}_2\text{CH}_2\text{)}_j\text{-}$ ,  $\text{-C(O)-NH-(CH}_2\text{)}_{1-6}\text{-NH-C(O)-}$ ,  
 $\text{-NH-C(O)-NH-(CH}_2\text{)}_{1-6}\text{-NH-C(O)-}$ , and  $\text{-O-C(O)-NH-(CH}_2\text{)}_{1-6}\text{-NH-C(O)-}$ , bivalent  
cycloalkyl group, an amino acid,  $\text{-N(R}^6\text{)-}$ , and combinations of two or more of any  
of the foregoing, wherein  $\text{R}^6$  is H or an organic radical selected from the group  
consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl,  
substituted alkynyl, aryl and substituted aryl, (h) is zero to six, and (j) is zero to 20.

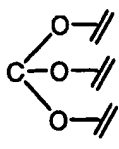
52. The polymer of claim 28, wherein the

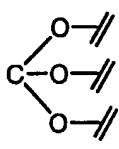


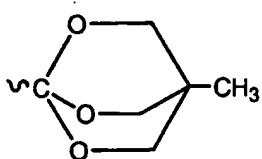
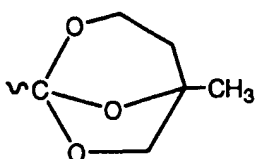
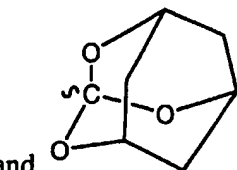
the following structure:



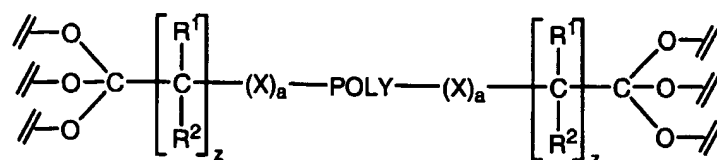
wherein each  $R^4$  is independently an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl.

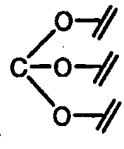
53. The polymer of claim 28, wherein the  moiety is in the form of a cyclic structure.

54. The polymer of claim 53, wherein the  moiety is selected from the group

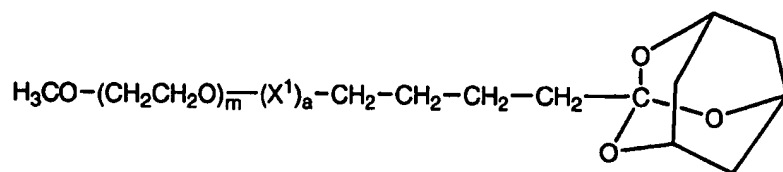
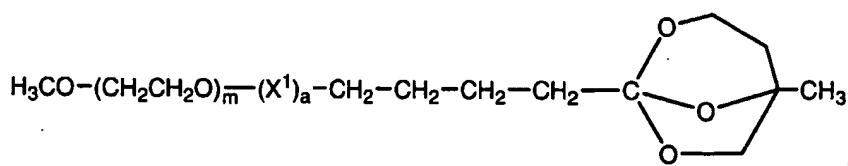
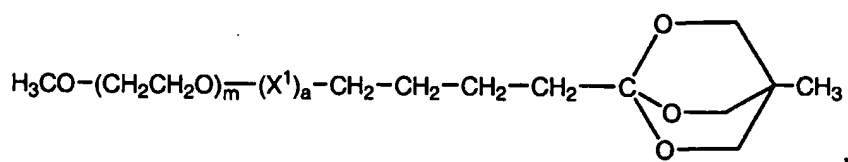
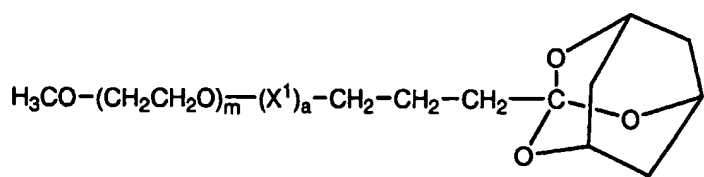
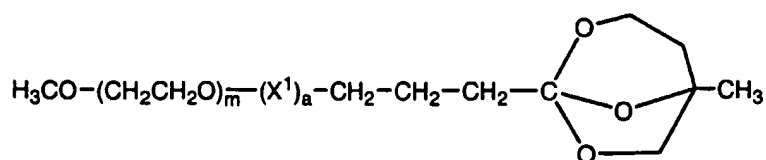
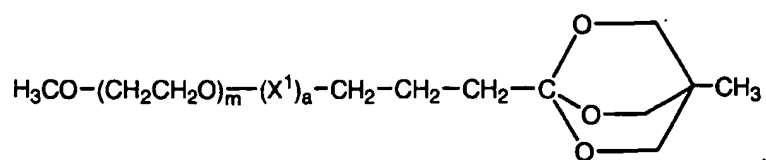
consisting of ,  and .

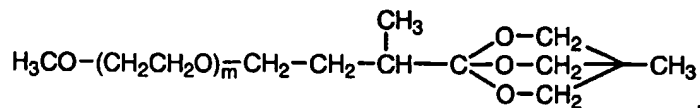
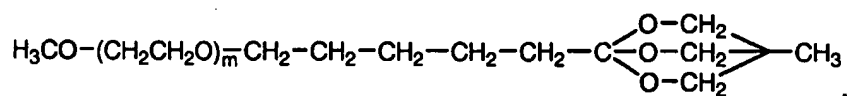
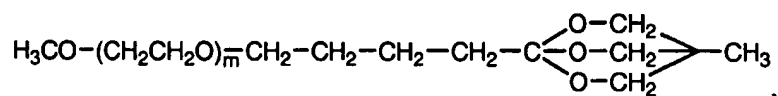
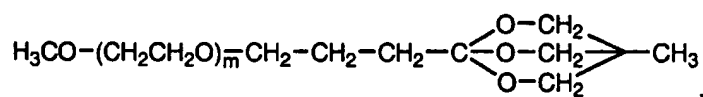
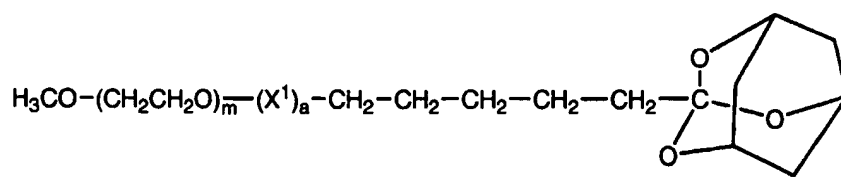
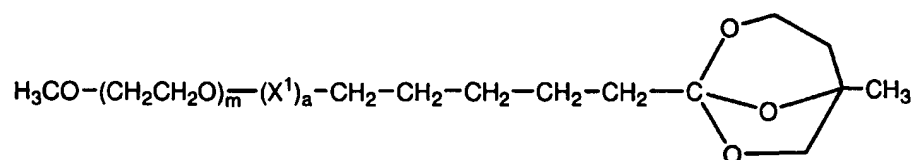
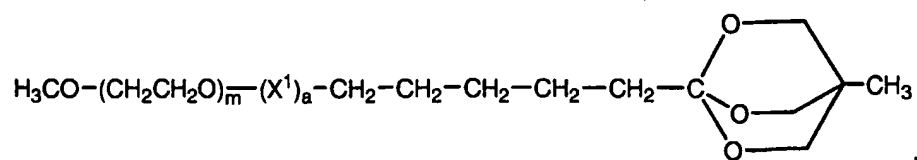
55. The polymer of claim 28, comprising the following structure:

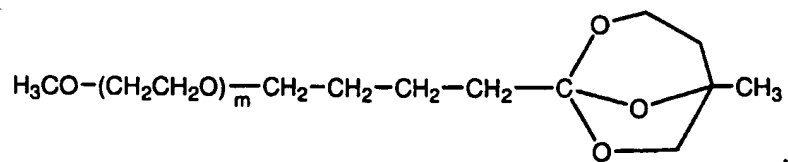
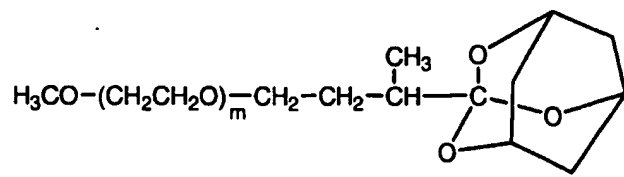
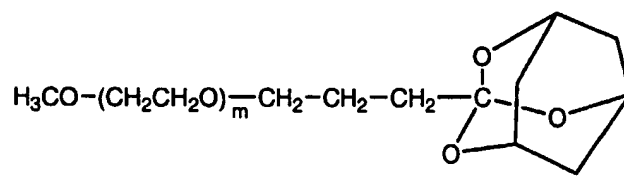
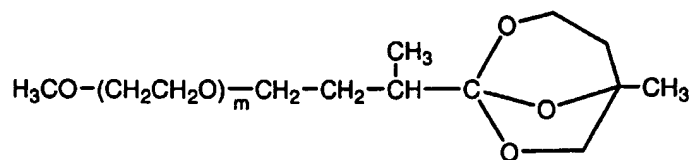
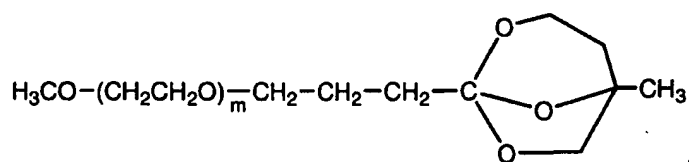
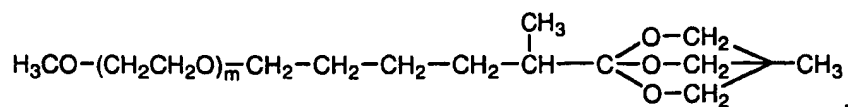
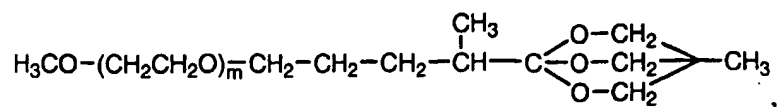


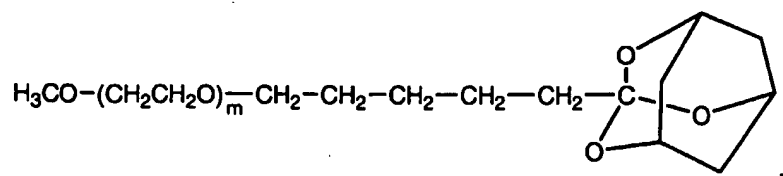
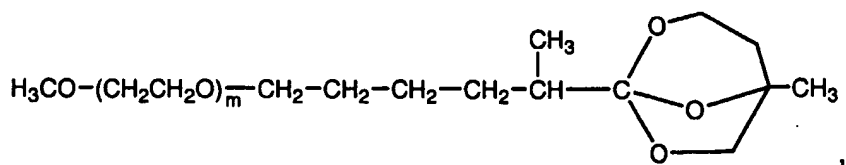
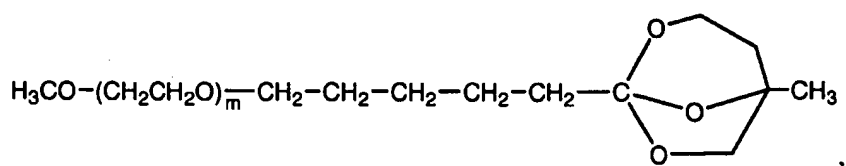
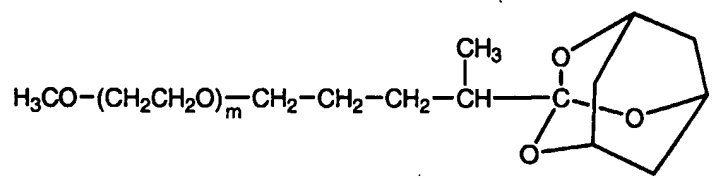
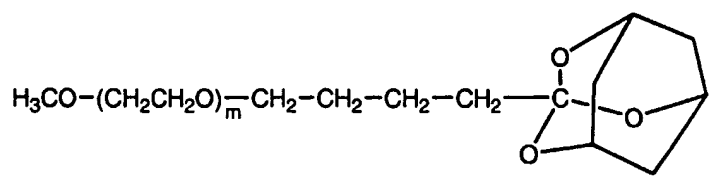
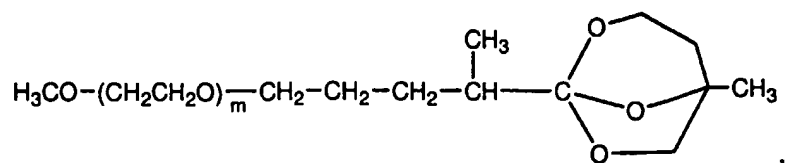
wherein POLY, each X, each (a), each  $R^1$ , each  $R^2$ , and each  are as described above.

56. The polymer of claim 28, selected from the group consisting of

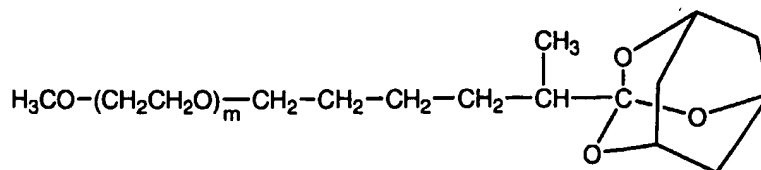








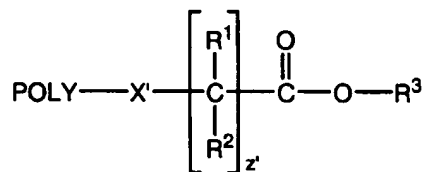
and



wherein (m) is 2 to 4000, (a) is zero or one, and X<sup>1</sup>, when present, is a spacer moiety.

57. A polymer comprising a water-soluble polymer segment and a carbon chain of four or more carbon atoms terminating in a carboxylic acid or nonaromatic ester thereof wherein the water-soluble polymer segment is covalently attached through one or more atoms to a carbon atom in the carbon chain that is at least four carbon atoms distal to the carbonyl carbon in the carboxylic acid or nonaromatic ester thereof, and further wherein when the water-soluble polymer segment is covalently attached through only one atom, the one atom is not O or S.

58. A polymer comprising the following structure:



wherein:

POLY is a water-soluble polymer segment;

X' is a spacer moiety with the proviso that when the spacer moiety is only one atom, the one atom is not O or S;

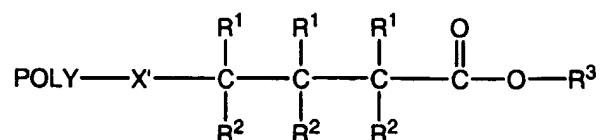
(z') is an integer from 3 to 24;

R<sup>1</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

$R^2$ , in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl; and

$R^3$  is H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, and substituted alkynyl.

59. The polymer of claim 58, wherein (z') equals three and the polymer is comprised of the following structure:



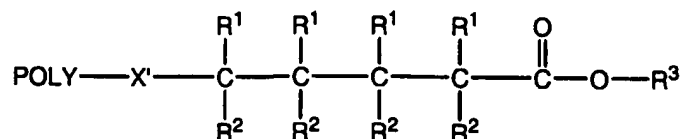
wherein POLY, X', each  $R^1$ , each  $R^2$  and  $R^3$  are as previously defined.

60. The polymer of claim 59, wherein  $R^3$  is H.

61. The polymer of claim 59, wherein each occurrence of  $R^1$  and  $R^2$  is H.

62. The polymer of claim 59, wherein the  $R^1$  attached to the carbon  $\alpha$  to the carbonyl carbon is alkyl, all other  $R^1$  variables are H, and all  $R^2$  variables are H.

63. The polymer of claim 58, wherein (z') equals four and the polymer is comprised of the following structure:



wherein POLY, X', each  $R^1$ , each  $R^2$  and  $R^3$  are as previously defined.

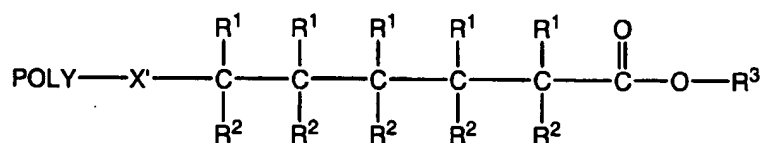
64. The polymer of claim 63, wherein  $R^3$  is H.



65. The polymer of claim 63, wherein each occurrence of  $R^1$  and  $R^2$  is H.

66. The polymer of claim 63, wherein the  $R^1$  attached to the carbon  $\alpha$  to the carbonyl carbon is alkyl, all other  $R^1$  variables are H, and all  $R^2$  variables are H.

67. The polymer of claim 58, wherein (z') equals five and the polymer is comprised of the following structure:



wherein POLY, X', each  $R^1$ , each  $R^2$  and  $R^3$  are as previously defined.

68. The polymer of claim 67, wherein  $R_3$  is H.

69. The polymer of claim 67, wherein each occurrence of  $R^1$  and  $R^2$  is H.

70. The polymer of claim 67, wherein the  $R^1$  attached to the carbon  $\alpha$  carbon to the carbonyl carbon is alkyl, all other  $R^1$  variables are H, and all  $R^2$  variables are H.

71. The polymer of claim 58, wherein POLY is selected from the group consisting of a poly(alkylene oxide)s, poly(vinyl pyrrolidone), poly(vinyl alcohol), polyoxazoline, poly(acryloylmorpholine), and poly(oxyethylated polyols).

72. The polymer of claim 71, wherein POLY is a poly(alkylene oxide).

73. The polymer of claim 72, wherein the poly(alkylene oxide) is a poly(ethylene glycol).

74. The polymer of claim 73, wherein the poly(ethylene glycol) is terminally capped with an end-capping moiety.

75. The polymer of claim 74, wherein the end-capping moiety is independently selected from the group consisting alkoxy, substituted alkoxy, alkenyloxy, substituted alkenyloxy, alkynyloxy, substituted alkynyloxy, aryloxy, substituted aryloxy, and hydroxy.

76. The polymer of claim 75, wherein the end-capping moiety is alkoxy.

77. The polymer of claim 76, wherein the alkoxy is methoxy.

78. The polymer of claim 75, wherein the end-capping moiety is hydroxy.

79. The polymer of claim 73, wherein the poly(ethylene glycol) has a nominal average molecular mass of from about 100 daltons to about 100,000 daltons.

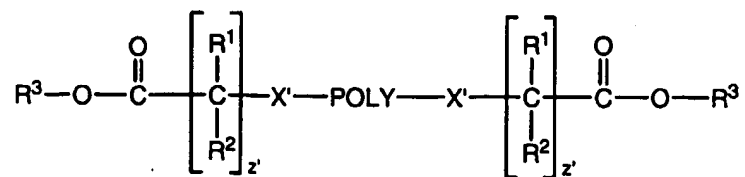
80. The polymer of claim 79, wherein the poly(ethylene glycol) has a nominal average molecular mass of from about 2,000 daltons to about 25,000 daltons.

81. The polymer of claim 80, wherein the poly(ethylene glycol) has a nominal average molecular mass of from about 5,000 daltons to about 20,000 daltons.

82. The polymer of claim 58, wherein X' is selected from the group consisting of -C(O)-, -C(O)-NH-, -NH-C(O)-NH-, -O-C(O)-NH-, -C(S)-, -CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -O-CH<sub>2</sub>-, -CH<sub>2</sub>-O-, -O-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-O-, -O-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-O-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-O-,

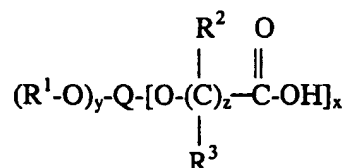
-O-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-O-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-O-, -C(O)-NH-CH<sub>2</sub>-,  
 -C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-,  
 -C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-, -C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-, -C(O)-O-CH<sub>2</sub>-, -CH<sub>2</sub>-C(O)-O-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-  
 C(O)-O-CH<sub>2</sub>-, -C(O)-O-CH<sub>2</sub>-CH<sub>2</sub>-, -NH-C(O)-CH<sub>2</sub>-, -CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-, -NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-, -CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-, -C(O)-NH-CH<sub>2</sub>-, -C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -O-C(O)-NH-CH<sub>2</sub>-, -O-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-, -NH-CH<sub>2</sub>-, -NH-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-NH-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-NH-CH<sub>2</sub>-, -C(O)-CH<sub>2</sub>-, -C(O)-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-C(O)-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-CH<sub>2</sub>-, -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-C(O)-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-, -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-,  
 -CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>2</sub>-C(O)-NH-CH<sub>2</sub>-CH<sub>2</sub>-NH-C(O)-CH<sub>2</sub>-CH<sub>2</sub>-,  
 -O-C(O)-NH-[CH<sub>2</sub>]<sub>h</sub>-(OCH<sub>2</sub>CH<sub>2</sub>)<sub>j</sub>-, -C(O)-NH-(CH<sub>2</sub>)<sub>1-6</sub>-NH-C(O)-, -NH-C(O)-NH-(CH<sub>2</sub>)<sub>1-6</sub>-NH-C(O)-, and -O-C(O)-NH-(CH<sub>2</sub>)<sub>1-6</sub>-NH-C(O)-, bivalent  
 cycloalkyl group, an amino acid, -N(R<sup>6</sup>)-, and combinations of two or more of any  
 of the foregoing, wherein R<sup>6</sup> is H or an organic radical selected from the group  
 consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl,  
 substituted alkynyl, aryl and substituted aryl, (h) is zero to six, and (j) is zero to 20.

83. The polymer of claim 58, comprising the following structure:



wherein POLY, each X', each (z'), each R<sup>1</sup>, each R<sup>2</sup>, and each R<sup>3</sup> are as previously defined.

84. A carboxylic acid or ester thereof comprising the following formula:



wherein:

R<sup>1</sup> is H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

Q is a residue of a polyhydric alcohol having x+y hydroxyl groups;

R<sup>2</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

R<sup>3</sup>, in each occurrence, is independently H or an organic radical selected from the group consisting of alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, and substituted aryl;

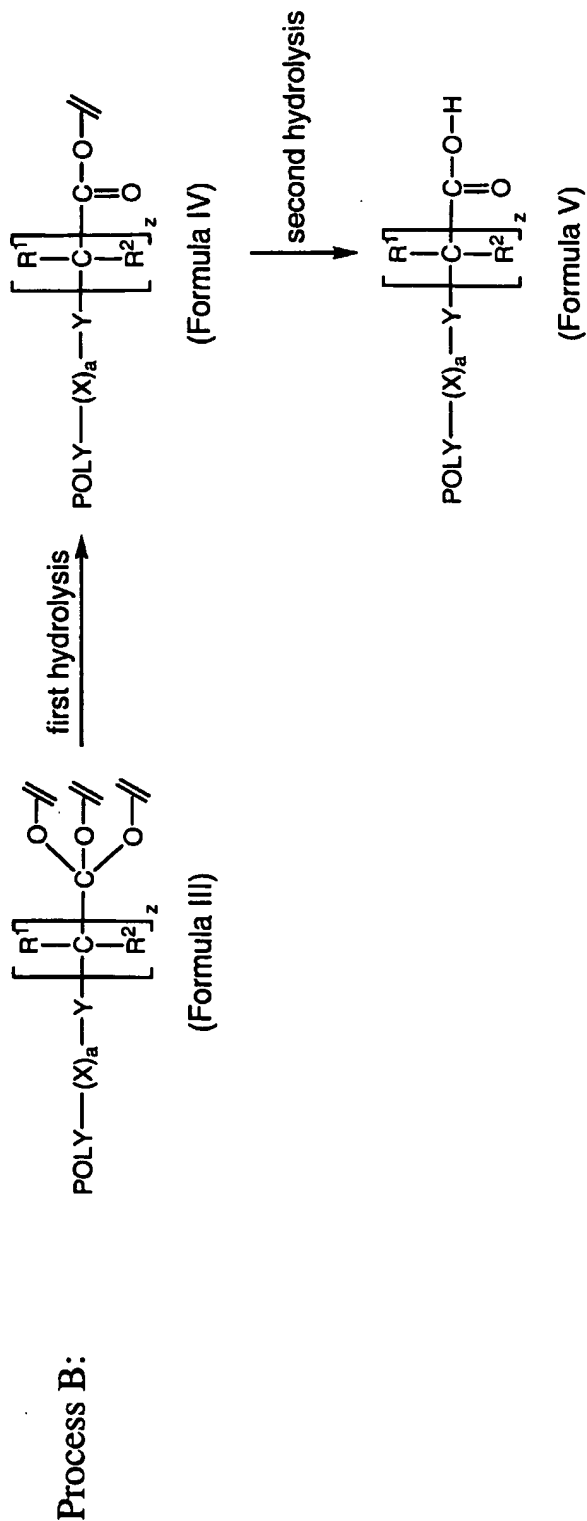
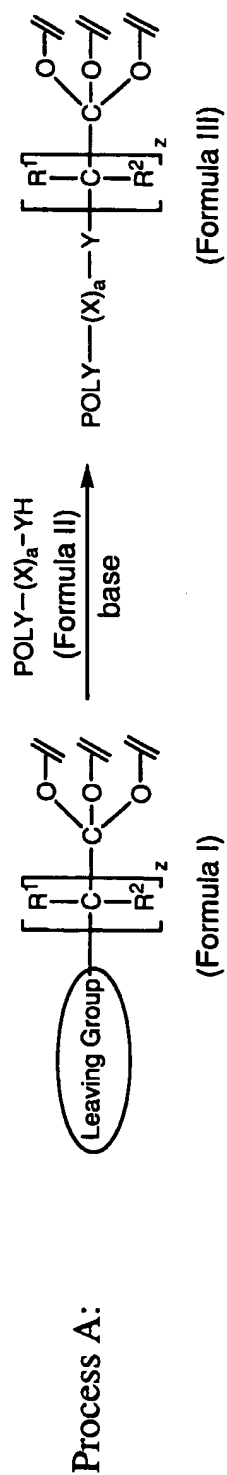
(x) is one to 20;

(y) is one to 20; and

(z) is four to 20.

85. A gel comprising the polymer of claim 57 or claim 58.

FIGURE 1



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- (72) Inventor; and
- (75) Inventor/Applicant (*for US only*): KOZLOWSKI, Antoni [PL/US]; 2209 Fairfax Drive, Huntsville, AL 35811 (US).
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(54) Title: METHOD FOR PREPARING WATER-SOLUBLE POLYMER DERIVATIVES BEARING A TERMINAL CARBOXYLIC ACID

(57) Abstract: A method is provided for preparing water-soluble polymer derivatives bearing a terminal carboxylic acid or ester thereof. The method involves the hydrolyzing an ortho ester of a water-soluble polymer so as provide the corresponding acid. In addition, the invention provides water-soluble polymers bearing a terminal carboxylic acid or ester thereof, intermediates and reagents useful in carrying out the method, as well as gels, pharmaceutical formulations, conjugates related to the described water-soluble polymer derivatives.

WO 2004/022629 A3

# INTERNATIONAL SEARCH REPORT

International Application No  
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**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 C08G65/329

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/064546 A1 (HARRIS J MILTON) 30 May 2002 (2002-05-30) column 2, paragraphs 27-30 regarding claims 57, 58 see present claim 82 for definition of the spacer moiety X'	1-85
X	US 2001/021763 A1 (HARRIS J MILTON) 13 September 2001 (2001-09-13) claims 1,12; examples 1-3	1-85
X	WO 97 03106 A (SHEARWATER POLYMERS INC ;HARRIS J MILTON (US); KOZLOWSKI ANTONI (U) 30 January 1997 (1997-01-30) claim 4; examples 1-3	1-85
	-/-	

☒ Further documents are listed in the continuation of box C.

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TOPCHIEVA I N: "SYNTHESIS OF BIOLOGICALLY ACTIVE POLYETHYLENE GLYCOL DERIVATIVES. A REVIEW*" POLYMER SCIENCE USSR, PERGAMON PRESS LTD. OXFORD, GB, vol. 32, no. 5, 1990, pages 833-851, XP000261916	26
A	page 839 the whole document	1-85
X	VERONESE F M: "Peptide and protein PEGylation: A review of problems and solutions" BIOMATERIALS, ELSEVIER SCIENCE PUBLISHERS BV., BARKING, GB, vol. 22, no. 5, March 2001 (2001-03), pages 405-417, XP002237938 ISSN: 0142-9612	26
A	page 407 the whole document	1-85